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# A DISCOVRSE of the Variation of the Cumpas, or Magneticall Needle.

## VVherein is Mathematicallie shewed, the manner of the obseruation, effects, and application thereof, made by W.B.

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## AND IS TO BE annexed to The New Attractiue of R.N.

1585.

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# To the trauailers, Sea-men, and Mariners of England.

HAuing of late (gentle Reader) receaued from the expert Artificer, Robert Norman, his Booke, entituled: The new Attractiue (who of the great good will, and affection he beareth, hath attributed in his Dedication, that, which I acknowledge not to bee due) in the which amongst other diuerse vertues and properties of the Magnes or Loadstone, he entreateth of the declining of the Needle touched therewith from the plaine of the Horizon, (a matter neuer before found or written of by anie.) For the further behoofe and benefit of all trauailers and Sea-men, I tooke occasion to inlarge the same with this discourse of the Variation of the Compasse, wherein I haue handled the whole varietie of that subiect, both Practicallie, and Mathimaticallie, to the end I might partlie satisfie both the vulgar, and also the learned sort. For, knowing the variation of the Compasse to be the cause of many errours and imperfections in Nauigation, and perceiuing that all those that haue as yet gone about to giue rules in that arte, haue left this (being a principall point, and euen the ground of all the rest) vntouched, or at least so sleightlie handled the same, that little or no benefit could bee gathered thereby: I haue heere set downe the sundrie waies to obserue the same at all times and places, that the inconuenience being knowen, might be considered off, and auoided. Wherein, although my chiefest intent hath bene to pleasure those that shall haue occasion to put the thing in practise by their owne trauaile and experience, yet because some of the rules are deducted from the

fountaines of the Mathematicall Sciences, and wrought by the doctrine of Signes and Triangles, which may seeme straunge in our English tongue, and wherwith few Sea-men are yet acquainted, I may seeme to haue missed of my first good meaning, but I would wish them to choose that which is plaine, and conformable to their capacities, and make their profit thereof, and for the rest vnderstand, that of such obseruations as they themselues cannot presentlie apply to the purpose, by others, that are throughlie instructed in these Mathematicall supputations, or by themselues when they shall attaine to the knowledge thereof, may be inferred such effectuall matter as is by these rules and precepts promised. Wherfore I would haue all Sea-men to vse such diligence in their trauailes, that no opportunitie be omitted, whē, or wher any obseruation may be made, either for the variation, or latitude of places, or of anie other necessarie poinct incident to Nauigation, & therof to keepe continuall notes & memoriall. For these obseruations there needeth not many troublesome Instruments, onely for the variation, the new Instrument in the end of this treatise I preferre before all other. And for eleuations, a plaine Astrolobe exactly made, and a crosse staffe are sufficient. (The Globe were also a verie good & necessarie Instrument: for besides many pleasant conclusions that may be tried by it, it dooth lighten verie much the conceits, for vnderstanding diuerse important poincts, but it is too troublesome [or otherwise not fit for euerie Mariner] to be carried to the Sea.) Vnto the which may be added the Topographical Instrumēt, for taking of distāces, & making descriptions vpon the land. With these Instruments, and the sailing Cumpas and Marine plat, (which are alwaies to be vnderstood the principall, and most necessarie Instruments for Nauigation, for by them onlie anie voiage may be made, but without them no Nauigation can bee performed,) the whole world may be trauailed, discouered, and described. These are sufficient for a perfect Mariner, and more then these were superfluous, onely the running glasses, leads, lines,

and

and such like appendances of the other excepted.

But to haue all these Instruments, and not to vnderstand the grounds how to vse them, were a great vanitie. Therfore I wish all Sea-men & trauailers, that desire to be cunning in their profession, first to seeke knowledge in Arithmetike & Geometrie, which are the groundes of all Science and certaine artes, of the which there is written in our English tongue, sufficient for an industrious and willing minde to attaine to greate perfection, whereby he may not onely iudge of Instruments, Rules, and precepts giuen by other, but also be able to correct them, and to deuise new of himselfe. And this not onely in Nauigation, but in all Mechanicall Sciences. As by the studious practise and exercise in these artes, haue attained to rare and singular knowledge: In Architecture, Vitriuuius the Romaine: In painting that famous Germaine Albertus Durerus: And in building of ships, Matthew Baker, our Countri-mā: And others in other faculties as they haue bene most skilfull heerein, so haue they excelled. Hauing these helps and grounds, with the Instrumentes before specified, a Mariner may be able to make description in Plat, of the coasts and Countries, & of the bankes, rockes, & sholds in the Sea, with the deapths, and other necessarie notes obserued in his owne trauailes, particularlie, and effectuallie according to the truth, (which is the chiefest part required in a perfect Mariner.) And not be alwaies tied to the reports of other, or to the Portugale, or Spanish Marine Plats, which are made by the Card makers of those Countries, men that are no trauailers themselues, but doe all things therein, by information, and vppon the credite of others, which onelie commit to memorie the forme & manner of the Sea coasts, with making some few notes of the lying of one place from another, which can neuer bee so perfect as the descriptions that are made vppon the present sight and view of places, albeit he be neuer so skilfull and cunning, that shall so carrie the same by memorie, how much lesse thē by the vnskilful. By this meanes the Card makers set down they know not what:

as may appeare by the descriptions of their owne coastes, which are verie grosselie and vnperfectlie done, whereas the Marine Plats ought to be described by such as can giue reason, and shew obseruation of euerie particularitie contained in the same, as well for the latitude of places, as the lying by the compasse of the Capes, Head-landes, Poinctes, Ilandes, Baies, Rockes, Sholds, &c. one from another, and the distances betweene them. The errours of those descriptions, I may not attribute to the Cardmakers, but to the vnskilfull Seamen of those Countries, for if they were otherwise, as they haue bene accounted the most skilfull of the world, those errours could not haue continued as they do: true it is, that for their great trauailes, they haue bene worthelie famous aboue all other nations, till now at length our Countrie-man Sir Frances Drake, for valarous attempt, prudent proceeding, and fortunate performing his voiage about the world, is not onelie become equall to anie of them that liue, but in fame farre surmounteth them all. But those Card makers, and all other that collect and gather Hydrographicall, and Geographicall descriptions of other mens trauailes or reportes: as their paines may be great, and deserue due commendations, so their doings may bring commoditie diuerselie. And in this behalfe Abrahamus Ortelius in his Theatrum, hath deserued immortall praise, for collecting together, and reducing into one commodious volume, the diuerse Plats and descriptions, made by diuerse and sundrie men. But amongst all those that haue made Geographical descriptions, I cannot a little meruaile at Gulielmus Postellus, who being a famous learned man, a great trauailer and Cosmographer, & Deane of the Kings professors in the Vniuersitie of Paris, in his vniuersal Map. Anno. 1580. besides that, it is generallie handled after such a grose and confused manner, that it might seeme rather to haue come from some rude vnskilfull, then from him so famous a Doctor, hath also in the imagined Countries about the North Pole, so corrupted it with his fond dreames & fantasticall inscriptions, attributing to those

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suppoſed lands, diuerſe people, as the Georgians and Hyperborians, and aſsigning there to be the higheſt hills of the world, and the people dwelling on them, to haue the continuall light of the Sunne, Sueta Zemlia found by the Engliſhmē, An. 1580. the holie Land, the place of the chiefeſt felicitie, the Hyperborean fields, & therfore the felicitie of the Moluccas, with many other ridiculous abſurdities: That by the groſe errours of this learned man in theſe matters, I am taught, that whatſoeuer fame goeth, or opinion is conceiued of anie man for profound learning, and ſmooth deliuering of their conceits, or whatſoeuer great promiſes are by themſelues made in theſe arts, to iudge of thē according to the works that come from thē, & not otherwiſe to be deceiued.

For auoiding prolixitie in this my Preface to ſo ſmall a volume, I referre the gentle Reader, to the worke it ſelfe. Yet by the waie it ſhall not be amiſſe, that I commend vnto you the Table of the Sunnes declinatiō (or Regiment) made by R.N. which is calculated for the preſent time, and differeth not from the truth in anie place aboue one minute, wheras in all other hetherto made and extant, there are great errors. Therefore, ſuch as otherwiſe cannot from time to time calculate their declinations, according to the place of the Sunne to be giuen by the Ephemerides, and table of Declination of Reinholdus, may boldly vſe this Regiment for 20. yeares, without anie ſenſible error. And ſo wiſhing my trauailes in this treatiſe, may doo ſuch good as I meant, I commit the ſame to your gentle conſtructions, & your ſelues to the Almightie. At Limehouſe the 26. of September.

Anno. 1581.

William Borough.

# A TABLE OF THE Chapters contained in the Treatise.


The first Chapter.

Of the Variation of the Cumpas or Magneticall Needle.

The second Chapter.

The manner how to vse the Instrument of Variation.

The third Chapter.

How to finde the Variation of the Cumpas or Needle at anie place, the eleuation of the Pole, and the situation of the Meridian vnknowen.

The fourth Chapter.

The eleuation of the Pole, and place of the Sunne giuen, how vpon the Globe, to finde the Variation of the Needle, by anie one obseruation either in forenoone or afternoone.

The fift Chapter.

How to finde the Variation by Arithmeticall calculation, vpon anie one obseruation in forenoone, or afternoone, the latitude of the place, and declination of the Sunne being giuen.

The sixt Chapter.

Another waie most generall, how to finde the Variation by one obseruation, either in forenoone or afternoone, the eleuation of the Pole, and Declination of the Sunne being giuen.


The

The Table.

The seuenth Chapter.

To finde the eleuation of the Pole, situation of the Meridian, and variation of the Needle, at anie place by the Sun, vpon two obseruations, either in forenoone or afternoone.

The eight Chapter.

Of the Pole of the Magnes.

The ninth Chapter.

Of the poinct Respectiue.

The tenth Chapter.

Of the application of the Variation, to the vse of Nauigation.

The eleauenth Chapter.

Of the inconueniences and defects in sailing, and in description of Countries, caused by the variation of the Cumpas.

The twelfth Chapter.

Of the Instruments and rules of Nauigation,

# Of the Variation of the Cumpas or Magneticall Needle.

## Chapter. I.

THE Variation of the Needle or Cumpas, is properly the arke of the Horizon contained betwæn the true Meridian of anie place, & the magneticall Meridian of the same, and is denominated to bee Easterlie or Westerlie, according to the position of the magneticall Meridian to the Eastwardes or Westwards of the true Meridian: And may be accompted either from the North parte, or the South part thereof, but vpon oppolite poincts it hath contrarie denominations.

The Magneticall Meridian is to be vnderstood a great circle passing by the Zenith & the Pole of the Magnes, diuiding the Horizon into two equall parts crossing ỹ same at oppolite poincts: which intersections or crossinges, are shewed by the Nædle or wiers of the Cumpas touched with the Magnes or the Loadstone.

The Azimuth of the Sunne is a great circle, passing by the Zenith and the true place of the Sunne: crossing the Horizon at right angles in oppolite poinctes, and diuiding the same into two equall partes. And it is sayde to be giuen when the distance thereof from the true Meridian is knowne.

The Azimuths of the Sunne vpon equall eleuations in forenoone and afternoone, haue equall distances from the true Meridian, so that the middle point of the whole difference of anie two Azimuths obserued vpon equall eleuations in forenoone or afternoone is the true Meridian.

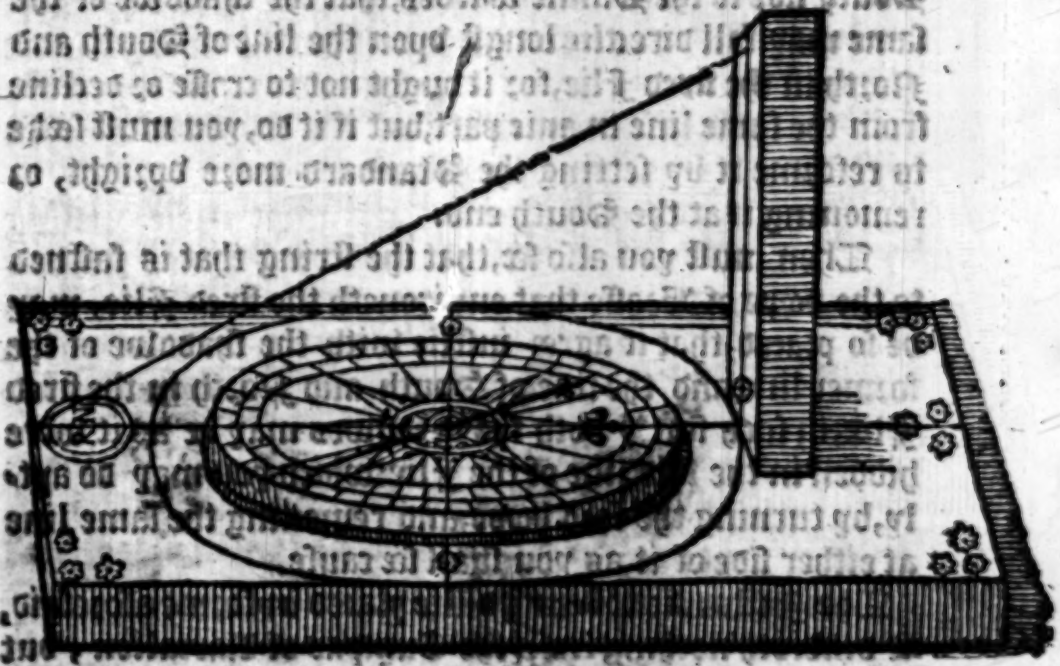
This difference of Azimuths is found vpon the Instrument

ment of Variation, by adding together the Variations of ỹ Sunnes shadowe, at equall elevations in forenoone and afternoone. The halfe whereof is the distaunce of the Azimuths from the true Meridian: the which compared with either of the same Variations of the Sunnes shadowe, the difference shall be the variation of the Nædle from the true Meridian.

Or else subtracting the lesser variation of the Sunnes shadow, from the greater (at equall elevations) the halfe of the remainer shall be the true variation of the Nædle from the Meridian.

But the Azimuth of the Sunne being otherwise given, and the variation of the shadow likewise giuen, the difference betweene them is the variation of the Nædle.

The variation of the Sunnes shadow, I call the Horizontall distance betweene the Azumuth of the Sun, and the magneticall circle, which are represented in the Instrument by the shadow of the line, and the Nædle.



## The manner how to vse the Instrument of Variation.

### The second Chapter.



Irst you must place the Instrument vppon some Stole, or other thing that is flat, so as it may stand leuell, and the Plummet in ẏ Standard which is placed at the North end of the fired Flie, may fall perpendicularlie with the line in the same Standard.

You must haue regard that in remouing ẏ Instrument to the Sunne as he goeth about, it may alwaies stand leuell as aforesaid.

You are then to consider, that the string that reacheth from the South part of the Instrument, to the top of the Standard, is the chiefest string to giue the Suns shadow, which must be so directed by turning the Instrumentes South side to the Sunne wardes, that the shadowe of the same may fall directlie longst vpon the line of South and North in the fired Flie, for it ought not to crosse or decline from the same line in anie part, but if it do, you must seeke to reforme it by setting the Standard more vpright, or remouing it at the South end.

Then must you also see, that the string that is fastned to the hoope of Brasse that enuironeth the fired Flie, may be so placed, that it agree iustlie with the shadowe of the former line, and the line of South and North in the fired Flie, in such sort ẏ both the shadowes may be as it were hidden in the said line of the Flie: which you may do aptly, by turning the said hoope, and remouing the same line at either side of it, as you shall see cause.

The Instrument being dulie placed in forme aforesaid, it differeth nothing from the Cumpas of Variation, but onelie in this point, that whereas the Flie of the Cumpas of Variation, is so turned by vertue of the Magneticall

wiers,

wiers, that the North point thereof doth shew the Pole of the Magnes, or line of Variation. In this Instrument, the North point of the Needle doth supplie that, which the North point of the Cumpas should doe. And the North point of the Flie which is fixed in the bottome of the Instrument, doeth alwaies answere to the shadowe that the Sunne giueth.

How to finde the variation of the Needle or Cumpas at anie place, the eleuation of the Pole, and scituation of the Meridian vnknowen.

## The third Chapter.

WHen you would obserue the variation in any place, you must begin in the forenoone, the sooner, the better, and the more effectuall may your obseruations bee, doe thus. Take your Astrolobe, and obserue dulie the height of the Sunne, for your more ease it shallbe best for you to note the same, when it agreeth to be iust vpon a degree, without anie consideration of minutes or fractions, and at the instant of the same height, turne your Instrument to the Sunne, so as the shadowe of the lines, may fal iustly vpon the line of South & North in the fixed Flie.

Then, when the Needle doth stand, looke directlie ouer the North point of the Needle, what degree and fraction, if ther be anie, doth answere vnto the same in the fixed Flie, that is to saie, how many degrees it is from the North of the fixed Flie, which you shall note diligentlie, and may saie, that so many degrees, &c. is the variation of the Suns shadow from the North, as the North point of the Flie is from the North point of the Needle, either Eastwards or Westwards as you shall finde the same. Thus may you obserue diuerse times, vpon seuerall degrees of the Suns

elevation. And like as you do in the forenoone, so must you also obserue the Sunnes elevation in the afternoone, vpon the same degree of height, and with the same side of the Astrolobe and Inder turned towards the Sunne, as it was in the forenoone (for auoiding of errour that may be in the Instrument) noting at euerie height what you finde the variation. And when the Sunne commeth to the Meridian, it shall be good that you exactlie obserue his elevation vpon the same, for knowing the true latitude of ỳ place: all which you shall set downe in forme following.

## Example.

### In Limehouse the sixteenth of October. Anno. 1580.

| Forenoone. | | | Afternoone. | | |
|---|---|---|---|---|---|
| Elevation of the Sunne. | Variation of the shadowe frō the North of the Needle to the Westwards. | | Elevation of the Sunne. | Variation of the shadow frō the North of the Needle to the Eastwards. | Variation of the Needle from the Pole or Axis. |
| Deg. | Degr. | Min. | Deg. | D. M. | D. M. |
| 17 | 52 | 35 | 17 | 30 0 | 11 17 ½ |
| 18 | 50 | 8 | 18 | 27 45 | 11 11 ½ |
| 19 | 47 | 30 | 19 | 24 30 | 11 30 |
| 20 | 45 | 0 | 20 | 22 15 | 11 22 ½ |
| 21 | 42 | 15 | 21 | 19 30 | 11 22 ½ |
| 22 | 38 | 0 | 22 | 15 30 | 11 15 |
| 23 | 34 | 40 | 23 | 12 0 | 11 20 |
| 24 | 29 | 35 | 24 | 7 0 | 11 17 |
| 25 | 22 | 20 | 25 | Frō N. to. w. 0. 8 | 11 14 |

The

The elevation of the Sunne vppon the Meridian 25.d. 58′. the declination 12.d. 30′. which I adde to the elevation, because the Sunne hath South declination, & therof amounteth 38.d. 28′. the elevation of the Equinoctiall, the which I subtract from 90.d. the rest is 51.d. 32′. the elevation of the Pole Artike.

Now are you to consider, that out of the greater variation of shadow vpon anie degree of the Sunnes elevation, is to be taken the lesser of the same degrees elevation, whether it be in the forenoone or afternoone (except the same varitions bee both one waie from the North of the Needle, which then are to be added) ỹ halfe of the remainer is the variation of the Needle or Cumpas from the Pole or true Meridian.

In the former observations, I do finde the greatest variation in the forenoone, for at 17.d. elevation, the variation is 52.d. 35′. from North to West: And at the same elevation in the afternoone, I finde the variation to bee but 30.d. 0′. from North to East. I take the lesser out of the greater, and finde remaining 22.d. 35′. the halfe thereof is 11.d. 17′. ½. So much I saie is the Pole Artike, and true Meridian line that palleth to the Pole by our Zenith at London, to the Westwards of the North that the Needle sheweth. And therfore the Needle or Cumpas varieth from the true North 11.d. 17′. ½. to the Eastwards.

Also at 25.d. elevation in the forenoone the variation is 22.d. 20′. from North to West: at the same elevation in the afternoone the variation is 0.d. 8′. from North to West. Now because the variations are both one waie, (that is to the Westwards) I adde them together (and so ought you to doe as often as you finde the variations so to agree) and I finde that they amount to 22.d. 28′. the halfe thereof is 11.d. 14′. which is the variation.

The variations of the Needle or Cumpas by the former observations, are set out towardes the right hand against euerie degrees elevation, and conferring them all together,

I doe finde the true variation of the Needle or Compas at Lymehouse to be about 11.d.½. or 11.d.¼. which is a point of the Compas iust or little more. So that in a Compas whose wiers are set directlie vnder the flowrs de Luce, the North and by West, and South, and by East pointes dos shew the true Meridian.

The eleuation of the Pole, and place of the Sunne giuen, how vpon the Globe, to finde the Variation of the Needle by anie one obseruation, either in forenoone or afternoone.

## The fourth Chapter.

IN the former declaration, the onelie waie to trie the variation, is by comparing of the seuerall correspondent obseruations of the Sunnes eleuation in the forenoone, with those of the afternoone, so that if the Sunne should be obscured, or by anie other occasion like obseruation cannot be made in the afternoone, then the former rule giueth not the desired purpose. Therefore I thought good to shew, how by anie one obseruation in the fore or afternoone, the eleuation of the Pole and place of the Sunne giuen, you may knowe the true Meridian and the variation of the Needle from the same in anie place, which thing may be done and aptlie demonstrated vpon the Globe, but most exactlie calculated by the Table of Signes.

To finde out the variation vpon the Globe, you must first set your Globe to stand dulie according to the eleuation of the Pole at the place proposed. Then seeke in the Ephemerides, for the true place of the Sunne that day, and note it with some small prick in the Ecliptike of ỹ Globe. And placing the Quadrant of altitude or moueable verticall, at the verticall point or Zenith, take the eleuation

of

of the Sunne obserued by the Astrolobe or other Instrument at the time proposed, and note it iustlie vppon the same quadrant of altitude. Then turne your Globe and Quadrant towards that part of the Horizon that the Sun was in at the time of the obseruation, till the pricke you made for the place of the Sunne in the ecliptike, concurre and agrée iustlie with the eleuation marked in the sayde quadrant of altitude. So shall you sée the Quadrant shew you vpon the Horizon, the Azimuth and distaunce of the Sunne from the true Meridian of that place, which you shall compare with the variation obserued vppon the Instrument at that instant of the Sunnes eleuation. And if they agrée and concur iust, then shall you be in the true and common Meridian, which sheweth the Pole of the world and Pole of the Magnes or Loadstone. But if they differ, you shall subtract the lesser from the greater, the remainer sheweth the variation. And if the variation vpon the Instrument be greater then the true distance of the Azimuth from the Meridian found vpon the Globe, the same surplus is to be accounted for variation: vpon the contrarie side of the Meridian: if it be lesse, it is to be accounted on the same side of the Meridian that the variation is taken, whether it be in the forenoone or afternoone. This precept needeth no further demonstration, then the Instrument it selfe, the Globe I meane.

But for example of the worke, I take the first obseruation, in the former Chapter specified, made at Lymehouse the sixteenth of October. 1580. in the forenoone, which is 17.d. eleuation, & variation 52.d. 35′. from North to West.

First I set my Globe at 51.d. 32′. for the eleuation of the Pole. Secondlie I take the place of the Sunne 2.d. 55′. m. and note it vpon the Eclipticke. Thirdlie, I note vpon the Quadrant of altitude, the eleuation of the Sunne. 17.d. This done, I moue the Quadrant of altitude towards the East of the Horizon, and turne the Globe till the pricke in

the Ecliptick for the place of the Sunne, doe agree iuſtly, with the eleuation noted vpon the quadrant of altitude, and finde the true Azimuth ſhewed by the laid quadrant vpon the Horizon to be neereſt, about 41.½. from the Meridian. And conferring the ſame with the variation found vpon the Inſtrument 52.d.35'. I finde the difference 11.d. 15'. And becauſe the obſeruation is noted to be in the forenoone frō the North to ẏ Weſt, or South to the Eaſt, and the variation vpon the Inſtrument greater then the Azimuth found on the Globe, I account the ſame frō ẏ North to the Eaſt, or from the South to the Weſt. So I conclude the variation at Lymehouſe to be about 11.¼. from North to Eaſt, or South to Weſt.

How to finde the variation by Arithmeticall calculation vpon anie one obſeruation in the forenoone or afternoone, the latitude of the place, and declination of the Sunne being giuen.

## The fift Chapter.

THE ſumme of the worke is to finde the arke of the Horizon betweene the Meridian and the Azimuth of the Sunne at the time of the obſeruation, which being compared with the variation found in the Inſtrument, the difference is the variation of the Needle. For attaining of the ſame arke. Firſt it is neceſſarie to haue the arke of the Equinoctiall betweene the Sunne at the time of the obſeruation, and the Meridian, which arke is thus found.

Multiplie the ſigne of the Sunnes Meridian altitude for the date propoſed, by the whole ſigne, the product diuide by the ſigne of the eleuation of the Equinoctiall (or the complement of the latitude) the quotient is the verſed ſigne or ſhaft of the ſemidiurnall arke, which you ſhall

note

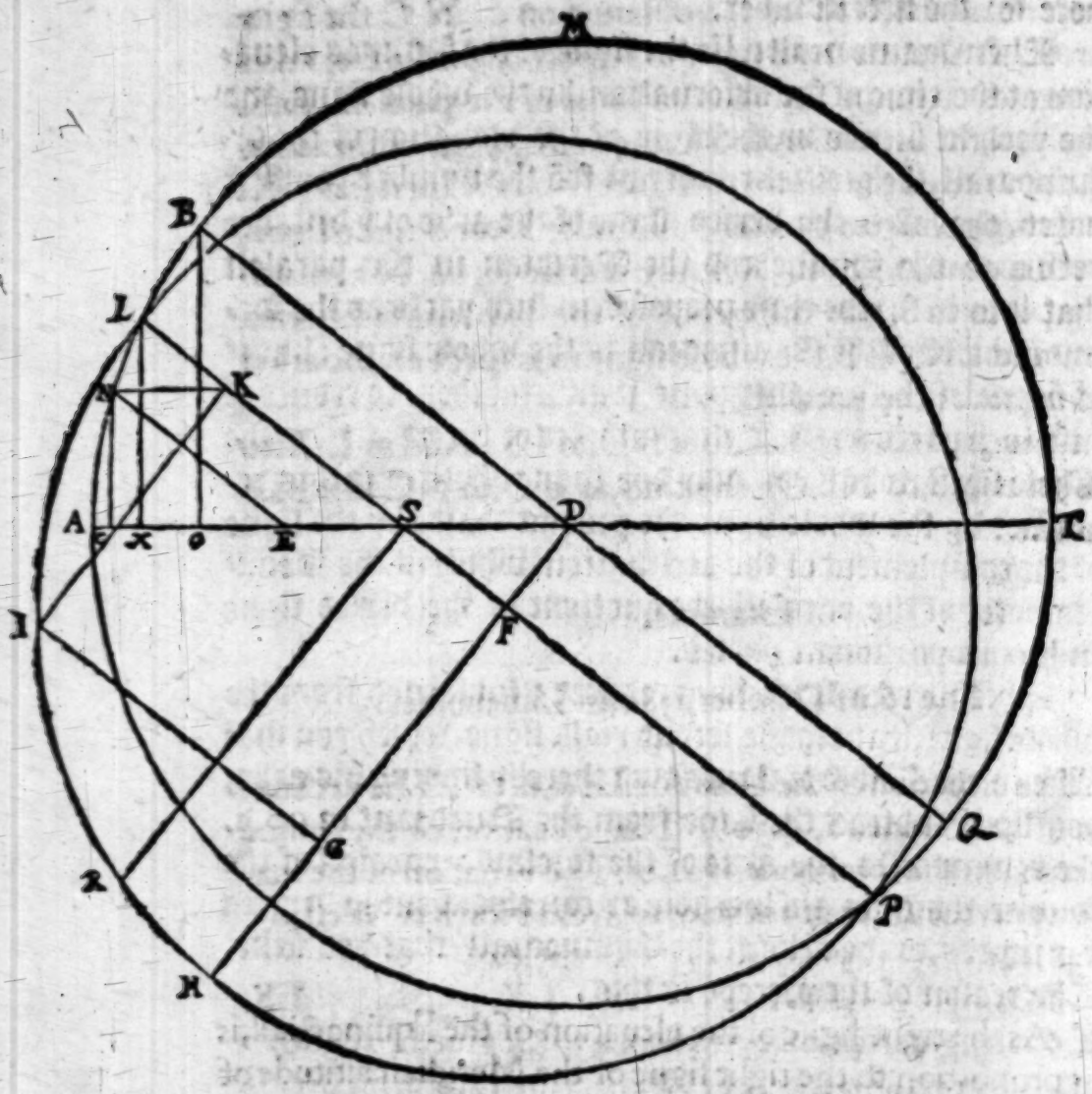
note for the first number.

Then againe multiplie the signe of the Sunnes elevation at the time of the observation, by the whole signe, and the product divide by the signe of the elevation of the Equinoctiall, the quotient subtract frō the number you first noted, the rest is the versed signe of the arke of ỹ distance betweene the Sunne and the Meridian in the paralell that it is in for the time proposed, in such parts as the Semidiameter of the Equinoctiall is the whole signe: but it is necessarie before you applie it anie further, to reduce it into such parts as the Semidiameter of the paralell is the whole signe, which you may doe thus: Multiplie this remainer by the whole signe, the product divide by the signe of the complement of the declination (which is the Semidiameter of the paralell) the quotient is the versed signe in his proportionall partes.

This versed signe thus reduced & subtracted from the whole signe, leaueth the second right signe, which you shal seeke in the Table of signes, and thereby finding his arke, you shall subtract the same from the Quadrant or 90.d. the remainer is the arke of the foresaide paralell of the Sunne, which is answerable or correspondent in degrees & minutes, to the arke of the Equinoctiall that you seeke. The reason of the precept is this.

As the right signe of the elevation of the Equinoctiall, is in proportion to the right signe of the Meridian altitude of the Sunne or anie Star: so is the whole signe, to the versed signe of the Semidiurnal arke. And againe, as the right signe of the meridian altitude, is to the right signe of the elevation of the Sun or Star at the time of the observation: So is the versed signe of the Semidiurnall arke of the same, to the excesse or difference betweene the same versed signe and the versed signe of the distance from the Meridian.

For the better understanding of the premises, I haue set downe this figure following, and wish the Reader to consider of the same with the 4. Pro. of the 6. of Euclide.




LEt AMT. bee the Meridian circle, B D Q. the common section of the Meridian and Equinoctiall their plaines, which is also the diameter of both circles.

ADT. the plaine of the Horizon. LHP. the parallell of the Sunne, which is described vpon the centre F. at the distance FL. which is the signe of the complement of the declination.

A B. the arke of the elevation of the Equinoctiall. B O. the first right signe thereof. A L. the arke of the Meridian altitude. L X. the signe thereof. A N. the arke of the Sunnes elevati-

eleuation at the time of the obſeruation. N C. the ſigne thereof. B D. the whole ſigne in reſpect of the former arkes and ſignes. L R. the Semidiurnall arke of the parallell. R. S. the firſt right ſigne therof. S L. the verſed ſigne of the ſame. L I. the arke of the Sunnes diſtance from the meridian. I K. the firſt right ſigne thereof. I G. the ſecond right ſigne, which is equall to K F. K. L. the vearſed ſigne. N E. which is equall to K S. the difference of the two vearſed ſignes. L S. and L K. L F. the whole ſigne in reſpect of the arkes and ſignes of the parallell.

Now as B O. is to L X. ſo is B D. to L S. And as L X. to N C. ſo is L S. to N E. Or elſe thus, as B O. to N C. ſo is B D. to N E.

## Example.

The 16. of October. 1580. in Limehouſe.

The eleuation of the Pole Artike. 51. d. 32′. The declination of the Sunne. 12. d. 30′. The eleuation of the Sunne obſerued in the forenoone. 17. d. 0′. The variation of the ſhadow vpon the Inſtrument 52. d. 35′. from North to Weſt.

| 38.28′ | 90.0′. | 25.58′. | |
|---|---|---|---|
| BO. | BD. | LX. | LS. |

If 62205. giue. 100000. — then. 43784 giueth. 70386.

| 38.28′ | 90.0′. | 17.0′. | |
|---|---|---|---|
| BO. | BD. | NC. | NE. |

Againe, if. 62205. giue. 100000. 29237. ſhall giue. 47001.

Now out of. LS. — 70386.
take. NE. — 47001.
Reſt. L K. — 23385.

Then if L F. 97629. the ſigne of 77. d. 30′. the complement of the declination, giue L F. 100000. then L K. 23385 giueth L K. 23952. the vearſed ſigne of the Arke I L. in his

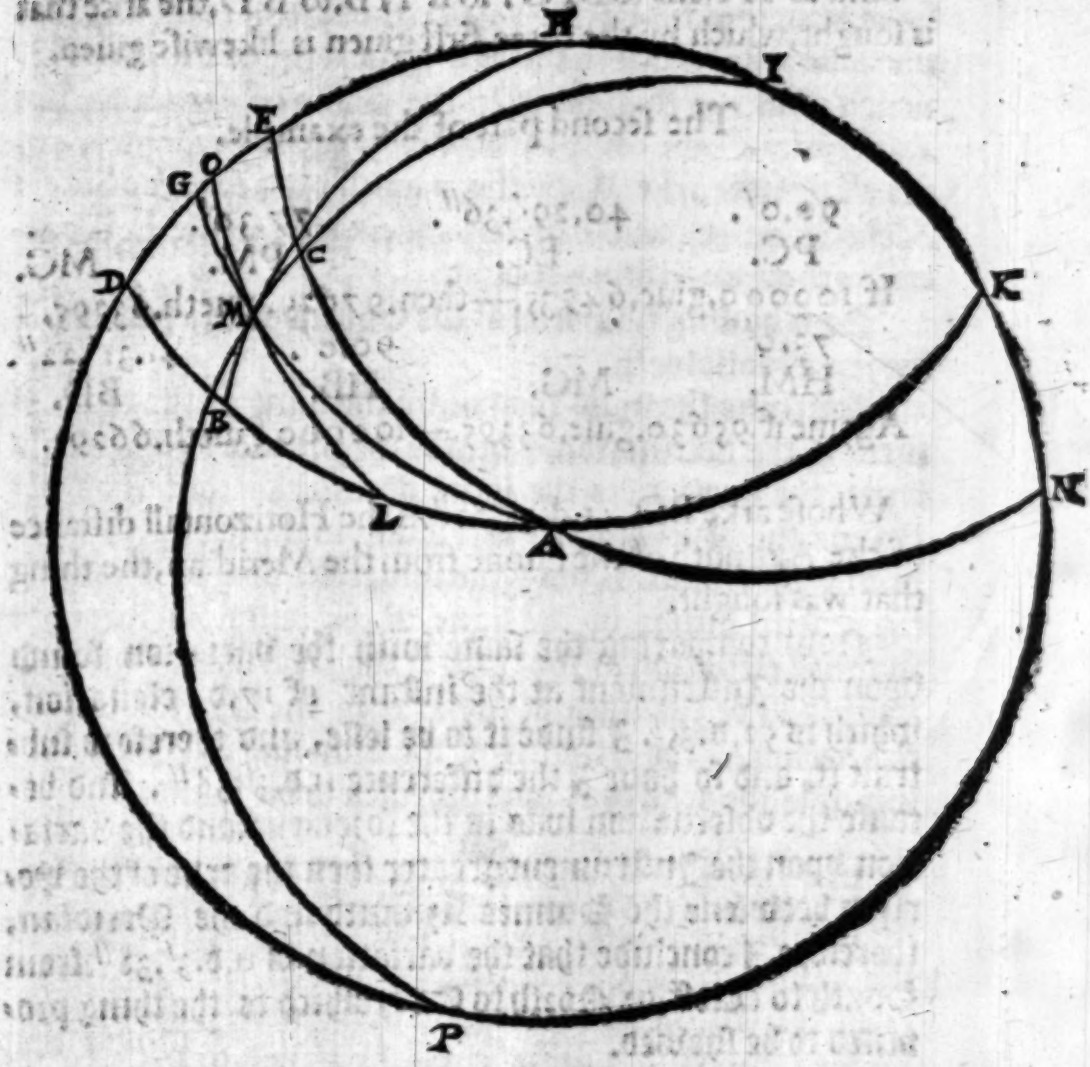
due partes. The same subtracted frō LF.100000. the whole signe, leaueth KF.or.IG.76048. the second right signe of the same arke, which is the first right signe of the arke IH. which arke you shall finde in the Table of signes to bee 49.d.30′.24″. the complemēt wherof to the quadrant is 40. d.29′.36″. the arke IL. of the paralell betweene the Sunne & the Meridian, whose correspondent arke in the Equinoctiall, is the arke that was sought.

Now hauing this arke of the Equinoctiall, you must worke as followeth.

Multiplie the signe thereof, by the signe of the complement of the declination, & diuide the product by the whole signe, the quotient is the signe of an arke contained betwæne the Sun and the Meridian, making right angles with ỳ Meridian. This signe multiplie by ỳ whole signe, the product diuide by the signe of the complement of the Sunnes eleuation at the time of the obseruation the quotient shall be the signe of the arke of the Horizon contained betwæne the Azimuth of the Sun and the Meridian, which is the arke that was proposed to bee found.

LEt DHNP. be the Meridian. DAK. the Horizon. EAN the Equinoctiall. M. the place of the Sunne in the heauen at the time of the obseruation. LMO. the paralell. HMB. the Azimuth or verticall circle passing by the Sunne. AMG. a great circle imagined to passe by the Sunne, and to crosse the Meridian at right angles. IMP. a great circle passing by the Poles of the world, and place of the Sunne at the time of the obseruation, commonlie called the circle of houres, or circle of declination. CM. the South declination of the Sunne. MP. the complement thereof to the quadrant. MG. the arke betweene the Sunne and the Meridian of the former imagined circle. AMGMO. the arke of the Sunnes paralel. EC. the correspondent arke of the Equinoctiall, which are giuen in the former worke. MB. the eleuation of the Sunne at the time of the obseru-

tion




tion. MH. the complement thereof. BD. the arke of the Horizon intercepted betweene the Azimuth and the Meridian, which is the thing required to bee found.

In this figure the Reader is to consider the manner of the spherical triangles, and to compare the signes of their sides, according to the doctrine of Copernicus, in the 14. Chapter of his first booke, & of Regiomontanus, his 25. and 27. Propositions of his 4. booke of Triangles.

As PC. is to CE. so is PM. to MG. but 3. of them are giuen,

giuen, therefore the fourth shall be knowen.

And as H M. is to M G. so is H B. to B D. the arke that is sought, which by the three first giuen is likewise giuen.

The second part of the example.

| 90.0′. | 40.29′.36″. | 77.30′. | |
|---|---|---|---|
| PC. | EC. | PM. | MG. |

If 100000. giue. 64935. — then. 97629. giueth. 63395.

| 73.0′ | | 90.0′. | 41.31′.22″. |
|---|---|---|---|
| HM. | MG. | HB. | BD. |

Againe if 95630. giue. 63395. — 100000. giueth. 66291.

Whose arke BD. 41. d. 31′. 22″. is the Horizontall distance of the Azimuth of the Sunne from the Meridian, the thing that was sought.

Now comparing the same with the variation found vpon the Instrument at the instant of 17. d. elevation, which is 52. d. 35′. I finde it to be lesse, and therefore subtract it, and so haue I the difference 11. d. 31′. 38″. And because the obseruation was in the forenoone, and the variation vpon the Instrument greater then the arke of the Horizon betweene the Sunnes Azimuth and the Meridian, therefore I conclude that the variation is 11. d. 31′. 38″ from South to West, or North to East, which is the thing promised to be shewed.

But comparing the same arke of the Horizon. 41. d. 31′. 22″. with the variation found at the correspondent elevatiõ in the afternoone, which is 30. d. 0″. I subtract the lesser from the greater, & finde the erreste 11. d. 31′. 22″. which should be the variation. And because the variation found vpon the Instrument is lesse then the Arke of the Azimuth vppon the Horizon, I account the variation on the same side of the Meridian, which is from South to West, or North to East.

This variete betweene the obseruation made in the forenoone

forenone, and that in the afternone, proceedeth either of the imperfection of the Instrument, or negligence of the obseruer. For in the rule there can be no errour, being grounded vpon Geometrical demonstration, then which, nothing can be more certaine.

The former precepts and examples do serue when the Sunne doth decline from the Equinoctiall either Northwards or Southwards. But if the Sunne be in the Equinoctiall, then the manner of the working is more easie & briefe. For if you multiplie the signe of the Sunnes eleuation at the time of obseruation, by the whole signe, & diuide the product by the signe of the eleuation of the Equinoctiall, which is the Meridian altitude, the quotient giueth the second right signe of the distance of the Sun from the Meridian, which is the first right signe of the complement of the same arke: And entering the table of signes with it, you shall finde his arke, which if you subtract from the quadrant or 90.d. leaueth the arke of the distance of the Sun from the Meridian. And hauing the same worke thus. If the signe of the complement of the eleuation of the Sunne at the time of the obseruation, giue the signe of the foresayd arke of distance, what shall the whole signe giue. Multiplie and diuide, the quotient shall be the sine of the arke of the Horizon contained betweene the Azimuth of the Sunne and the Meridian. Which arke being compared with the variation of the Instrument in manner as before is shewed, giueth the variation required.

But the Sunne being in the Equinoctiall, if the place where the obseruation is made, be likewise vnder the same circle, then is the variation most easilie obserued, for that the Equinoctiall is the Azimuth of East and West, therefore turning your Instrument onelie to receiue the shadowe of the Sunne, and loking then to the North poinct of the Needle, if you finde the same to aunswere to the Quadrant or 90.d. you shall bee in the Meridian of the Magnes, which palleth by the Poles of the world, but if it

doe differ from 90.d. the same difference is the variation of the Needle.

But admitting the obseruer to be vnder the Equinoctiall, and the Sunne to haue declination, then the proportion of the signe of the complement of the elevation at the time of the obseruation, vnto ẏ signe of the declinatiõ, shall be such, as ẏ whole signe, is to the signe of ẏ arke of ẏ Horizon included betweene the Azimuth of East & West, which is the Equinoctiall it selfe, and the Azimuth of the Sunne for the time of the obseruation, the complement whereof giueth the true Meridian, which complement you may compare with the variation shewed vppon the Instrument, the difference is the Variation.

Diuerse other cases might be proposed, and rules giuen for them, which for breuitie I omit.

But one thing I thought good to admonish you by the waie, that whereas I haue shewed in the first part of this proposition the manner to finde the two versed signes, the one of the Semidiurnall arke, the other of the arke of the distaunce of the Sunne from the Meridian. By the first, the Semidiurnall arke being founde & reduced into houres and minutes of time, is shewed the iust halfe quantitie of the daie. And by the arke of the other lykewise reduced, the houre of the daie, or ẏ time contained betweene the nonestæd and the instant of the obseruation. As in the same example.

The verses signe of the Semidiurnall arke L S. is giuen 70386. in such parts as the Semidiameter of ẏ Equinoctial BD. is 100000. therfore I reduce ẏ same into such parts as the Semidiameter of the paralel L F. is. 100000 and finde it to be 72095. which subtracted from the whole signe L F. 100000. there resteth S F. 27905. which is the second right signe of the Semidiurnall arke L R. and the right signe of R H. 16.d.12′. which is the complement of the Semidiurnall arke L R. wherefore subtracting it from the quadrant L H. or 90.d. resteth 73.d.48′.

the

the Semidiurnall arke LR. the same reduced into partes of time allowing 15.d. for an houre $15^{l}$. for a minute, & $15^{ll}$. for a second of time, and for euerie degrée 4. minutes of time, for euerie minute $4^{ll}$. and for euerie second $4^{lll}$, &c. I finde the time of that arke from the point ascendent, to the Meridian, which is halfe the daie, to be 4. houres $55^{l}$. $12^{ll}$. and consequentlie the whole daie, beeing the 16. of October aboue written, to be 9. houres $50^{l}.24^{ll}$. long.

This example maye serue for a generall precedent, whiles the Equinoctiall is betweene the Sunne and the eleuated Pole, but if the Sunne be betweene the eleuated Pole and the Equinoctiall, then will the versed signe fall out to be greater then the whole signe, and the Semidiurnall arke to exceede a Quadrant. Wherefore hauing reduced the same into his proportionall parts, as before is shewed, subtract from it the whole signe, the surplus is the signe of the excesse of the Semidiurnall arke aboue a quadrant, which being added to the Quadrant, giueth the Semidiurnall arke.

By the other versed signe of the distance of the Sunne from the Meridian, which is LK. 23952. in such partes as the whole signe or Semidiameter LF. is 100000. subtracted from the whole signe, is giuen KF. 76048. the second right signe of the same arke of distance, and the first right signe of 49.d.$30^{l}.24^{ll}$. which is the complement of the arke of the Sunnes distance from the Meridian: therefore subtracting the same from 90.d. resteth 40. d.$29^{l}.36^{ll}$. the arke of the distance betweene the Sunne and the Meridian, which being reduced into partes of time as before, giueth 2. houres $41^{l}.58^{ll}$. and the same (because it is in the forenoone) deducted from 12. houres the nonesteed, resteth 9. houres $18^{l}.2^{ll}$. the iust instant of the time of the daie.

But if this versed signe be found to be greater then the whole signe (as it may when the Sunne is betweene the Equinoctiall and the eleuated Pole, and before the houre

of fyre in the morning, and after the houre of fyre in the euening) then doth the arke of distance consequentlie exceede a Quadrant, the signe of this exceſſe is the surplus of the versed signe aboue the whole signe. Whose arke added to the Quadrant giueth the arke of the Sunnes distance from the Meridian, and reducing the same into partes of time, is giuen the instant of time of the obseruation.

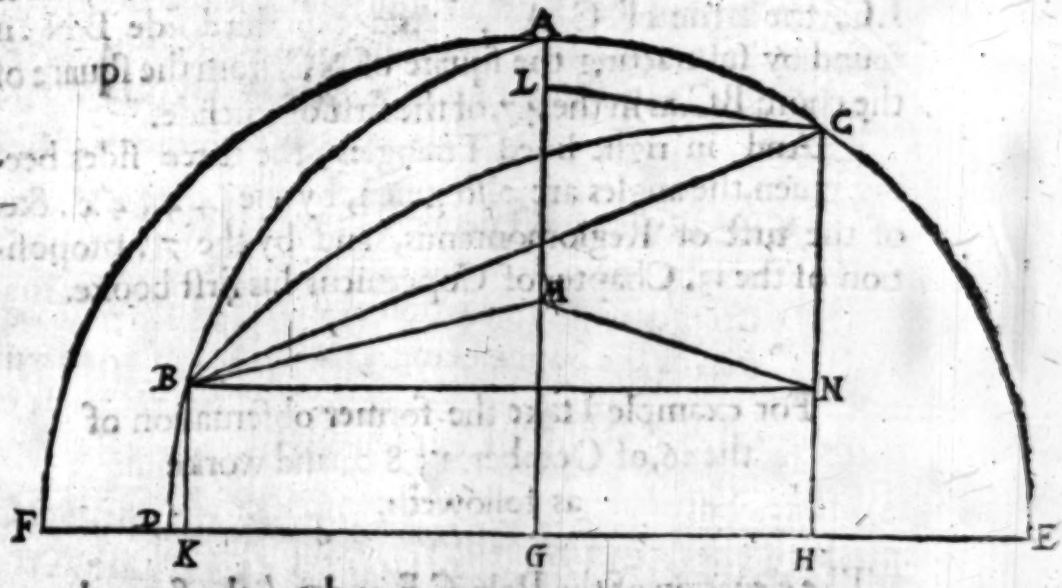
As by this meanes (the eleuation of the Sunne beeing preciselie obserued and latitude knowen,) the instant of time of the daie is giuen more exactlie, then by anie Clocke, Diall, or other Instrument. So if there might be had a portable Clocke that would continue true the space of 40 or 50. houres together (if longer time the better) then might the difference of longitude of anie two places of knowen Latitudes, which conuenientlie may bee trauailed within that time, be also most exactlie giuen. And in this sort trauailing and obseruing from place to place, might the longitudes of anie Countrie bee perfectlie described.

Another waie most generall, how to finde the Variation by one obseruation either in the forenoone or afternoone, the eleuation of the Pole and declination of the Sunne being giuen.

## The sixt Chapter.

FOR the accomplishing of this proposition, you are to imagine a sphericall Triangle vpon the superficies of ỹ Globe, whose sides must be. First, the portion or arke of the meridian betweene your Zenith and the Pole, which is the complement of the latitude. The second the arke of ỹ vertical circle contained betweene your Zenith & the Sun, which is ỹ cõplement of ỹ Sunnes eleuation at the time of the obseruation. The

third ſide is an arke of the circle of declination comprehended betweene the Sunne and the eleuated Pole, this arke is found by adding, or ſubtracting, the declination of the Sunne, to or from, the Quadrant or 90. d. which muſt be done with this conſideration, that if you be on the ſame ſide of the Equinoctiall that the Sunne is, you are to ſubtract the declination from the Quadrant. If on the other ſide, to adde it to ỹ ſame, ſo haue you the three ſides of the ſphericall triangle giuen. Then the ſubſtance of the worke conſiſteth in finding the quantitie of the angle of the ſame triangle at the Zenith, for the complement thereof to the Semicircle or two right angles, is the Horizontall diſtance of the Sunnes Azimuth from the Meridian, which being compared with the variation of the Suns ſhadowe vpon the Inſtrument, giueth the thing required.




LEt FACE. be the Meridian, wherein A. the Zenith, C. the Pole. AD. the verticall circle or Azimuth of the Sunne paſsing by B. the place of the Sunne at the time of the obſeruation. B. D. the eleuation of the Sunne. BA. the complement of the eleuation. AC. the complement of the latitude. BC, the arke of the circle of declination, or

the chord of the same arke, F G E. the plaine of the Horizon.

Now from the three angles of the triangle ABC, let fall three perpendicular lines to the plaine of the Horizon, AG. CH. and BK. and by the 6. of the 11. of Euclide, these three lines shall be paralells.

Then let fall a perpendicular line from C. vpon AG. in the poinct L. from B. another perpendicular vpon the same line AG. at the poinct M. And from the same poinct M. erect a perpendicular line to N. which shall be paralell and equall to LC. Then ioyne B. and N. together. So haue you a right lined triangle. B M N. whose angle at M. is equall to the angle A. of the sphericall triangle A B C. By the 4. definition of the 11. of Euclide, for the like reason is of obtuse angles as of acute or sharpe. And the sides thereof BM. and MN. are giuen BM. the signe of BA. and MN. equall to LC. the signe of C A. And the third side B N. is found by subtracting the square of NC. from the square of the chord BC. as in the 47. of the first of Euclide.

And in right lined Triangles, the three sides beeing giuen, the angles are also giuen, by the 44. 45. &c. of the first of Regiomontanus, and by the 7. proposition of the 13. Chapter of Copernicus his first booke.

For example I take the former obseruation of the 16. of October. 1580. and worke as followeth.

The eleuation of the Pole C E. 51. d. 32'. the signe thereof CH. 78297. The eleuation of the Sunne BD. 17. d. 0'. the signe thereof B K. 29237. The arke B C. 102. d. 30'. the chord thereof B C. 155970. The complement of the eleuation of the Sunne B A. 73. d. 0'. the signe thereof BM. 95630. The complement of the latitude A C. 38. d. 28'. the signe thereof L C. 62205. equall to M N.

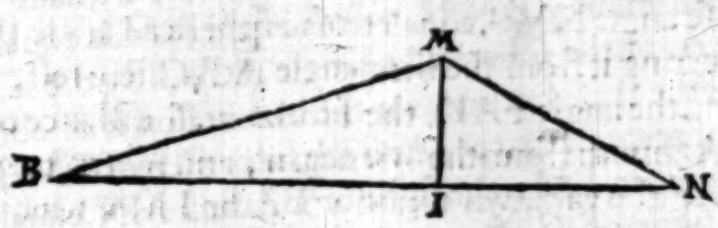
Now

Now out of CH. 78297. ſubtract NH. equall to BK. 29237. Reſt. NC. 49060.

Then out of the chord BC. ſquared.—2432851257 6.
Take the ſquare of NC.——————2406883600.

Reſt the ſquare of BN.—————— 21921628976.
The roote thereof is 148059. the ſide BN.

So are the three ſides of the triangle giuen. { BN. 148059. / MN. 62205. / BM. 95630.




Now to finde the angle M.I ſubtract from the ſquare of BM. the bigger ſide, which is. 9145096900. the ſquare of MN. the leſſer ſide, which is 3869462025. Reſt 5275634875 which diuided by the baſe BN. 148059. giueth 35631. which number I take out of the ſayd baſe reſt. 112428. the halfe thereof 56214. is IN. the leſſer caſe or ſhorter parte of the baſe diuided by the perpendicular line MI. falling vpon the ſame from the obtuſe angle M. which ſubtracted from the whole baſe BN. 148059. leaueth IB. 91845. the greater caſe or longer part thereof.

Now it is manifeſt that theſe two caſes or partes of the baſe BI. & IN. are the ſignes of the two ſharp angles IMB. and NMI. made of the obtuſe angle M. by the perpendicular falling from the ſame angle to the baſe, and the arkes of them ioyned together, are the quantitie of the obtuſe angle NMB.

Therefore to reduce them to the numbers of the ſignes, firſt for the greater caſe BI. making BM. the whole ſigne, ſaie.

BM.

BM. BM. BI. BI.

If 95630.giue.100000.—then shall.91845. giue 96041.

The arke thereof is 73.d.49′.38″. Againe for the lesser case, making MN. the whole signe, saie.

MN. MN. IN. IN.

If 62205.giue 100000.—then 56214.giueth 90376.

Whose arke is 64.d.38′.45″. And adding these two arkes together, they giue 138.d.28′.23″. the arke or quantitie of the obtuse angle NMB. equall to the sphericall angle BAC. and deducting it from the Semicircle 180.d. there resteth 41. d.31′.37″. the angle FAD. the Horizontall distance of the Sunnes Azimuth from the Meridian, and subtracting that frō 52.d.35′. the variation found vpon the Instrument from North to West in the forenoone, resteth 11.d.3′.23″. the variation of the Needle from the Meridian, the thing that was proposed to be found. And comparing the same with the afternoones obseruation, you shall finde it 11.d.31′.37″. the cause of this difference I haue declared in the former Chapter.

If the Reader be delighted with varietie of demonstration of this matter, let him peruse the 34. Proposition of the 4. of Regiomontanus, & the 13. proposition of the 14. Chapter of the first booke of Copernicus.

But whereas you see this calculation to differ from the former in some odde seconds, the reason thereof is not as it might be taken the different nature of the rules, but in working thereof, omitting the fractions in the diuisions, and neglecting the proportionall partes of the signes and arkes.

In these examples I haue vsed the abridged table of 100000. the whole signe, which though it giue some ease in the working, yet it is not so exact as that of 10000000. of Erasmus Reinholdus. Vnto the which, with his Canon fœcundus answerable to the same, if the third Canon of the

Hypo-

Hypothenuſaes were annexed, we ſhoulde haue an entire Table for the doctrine of triangles, that might worthelie be called The Table of Tables. Which thing though Georgius Ioachimus Rheticus, haue well begun & framed it orderlie from ten minutes to ten: yet is it left very rawlie for ſuch as deſire the exact truth of things. I haue therfore for mine owne caſe and vſe, calculated the complement of this Table, and almoſt ended it, for the whole quadrant from minute to minute: which if in the meane time before I haue finiſhed, I ſhall not finde it extant by anie other, I will publiſh it for the commoditie of all ſuch as ſhall haue occaſion to vſe the ſame for Nauigation and Coſmographie.

To finde the eleuation of the Pole, ſcituation of the Meridian, and variation of the Needle, at anie place by the Sun, vpon two obſeruations, either in forenoone or afternoone..

## The ſeuenth Chapter.

WHereas in the three laſt Chapters, the grounds of the calculations conſiſt in the eleuation of the Pole to be giuen, which thing to know is no leſſe difficult, then the chiefe matter that is by them required. For the common preceptes, which as yet haue chieflie ben giuen for ỹ finding therof, depend onelie vpon the obſeruation of the Meridian altitude of the Sunne or Starres, or elſe vpon certaine falſe and groſe rules of the guards and Pole Starre. Therefore I haue thought good, that as I haue ſhewed the waie to knowe the variation, vppon anie one obſeruation, either in forenoone or afternoone, the latitude of the place preſuppoſed: ſo likewiſe vpon two obſeruations by the Sunne, either in forenoone or afternoone, to ſet downe the waie and manner howe to

finde the eleuation of the Pole, ſcituation of the Meridian, and variation of the Needle in anie place by the Globe.

But this you muſt alwaies regard that your two obſeruations may haue conuenient diſtance of time betweene them, the greater the better: So as the higher eleuation be not taken nere the Meridian, the lower eleuation the nerer it is taken to the Azimuth of Eaſt or Weſt, or to the Horizon, the better, with which eleuations you are to note the difference of the Sunnes Azimuths or variations founde by the ſhadowe vppon the Inſtrument exactlie, for without that the eleuations onelie are in vaine.

Firſt it is requiſite that your Globe bee ſo fitted, that the meridian circle and the Horizon doe croſſe each other at right angles, and diuide themſelues equallie into Semicircles. And alſo that the Quadrant of altitude (or moueable verticall) be placed dulie vpon the Meridian circle at the Zenith, ſo as beeing turned circularlie, it may touch the Horizon equallie in euerie part. Theſe thinges beeing duly conſidered, there needeth not anie further regard to be had for placing of the Globe, onely this you may reſpect in ſetting the pole at aduentures aboue the Horizon betweene it and the Zenith, that the meridian circle may cut ỹ Horizon in iuſt degrees, ſo may your quadrant of altitude be placed at your Zenith iuſtly vpon a degree alſo.

Then muſt you faſten your Globe to the Horizon, ſo as it may remaine immoueable, but in faſtning the ſame you muſt regard that you force it not from one ſide of the Horizon to another, but that it reſt equidiſtant in the ſame. And hauing your Globe thus diſpoſed, it is readie for you to applie your obſeruations vpon, which you ſhall thus doe.

Firſt, take your higheſt eleuation, and note it vpon your Quadrant of altitude, and place the end of the ſaid Quadrant vpon the Horizon at 10. 15. or 20. d. from the Meri-

dian circle(but the nèerer you set the same to the Meridian, the more conuenientlie, without impeachment, will your triall bée made.) Then giue a pricke vppon the Globe in the Azimuth, that the Quadrant sheweth at the degrée of the eleuation noted vppon the Quadrant, then againe note the lesser eleuation vpon the Quadrant of altitude, and remoue the same vpon the Horizon (from that place where it was first fixed, towards the Azimuth of East or West (which shall be nèerest the same) so many degrées as you finde the difference of Azimuths betwœne the two eleuations by the shadowe of the Sunne, vpon the instrument of Variation, and staying your quadrant of altitude vpon that poinct of the Horizon: note also your lesser eleuation in the same Azimuth vpon your Globe. This done, you must haue a paire of Calliper Cumpasses, such as may conuenientlie reach to 113.d. ½. of the Equinoctiall of your Globe, (which is a Quadrant, and the greatest declination of the Sun) then you must consider which of the Poles of the worlde is eleuated aboue your Horizon, and whether your declination be towards, or from that pole, ỳ is to saie, whether the Sun be betwœne the eleuated Pole & the Equinoctiall, or the Equinoctiall betwœne the Sun & the Pole. If the Sun be betwœne the Pole & the Equinoctial, ther are you to subtract the declination from 90.d. If the Equinoctiall be betwœne the Sunne and the Pole, you must adde the declination to 90.d. And take the same remaining or collected number of degrées, &c. with your cumpasses vpon the Equinoctiall. And set the one end of your compasse at the pricke made vpon your Globe, for the highest obseruation, & with the other end describe an arke or pèce of a circle, vpon the same side of the Meridian that your pricke is on, from the Meridian to the Horizon. Then againe with your cumpas vnaltered, setting the one fot in the pricke for the lowest obseruation, describe another pèce of a like circle crossing ỳ former. The poinct of ỳ intersection, or crossing of these two circles, is ỳ eleuated pole, to the

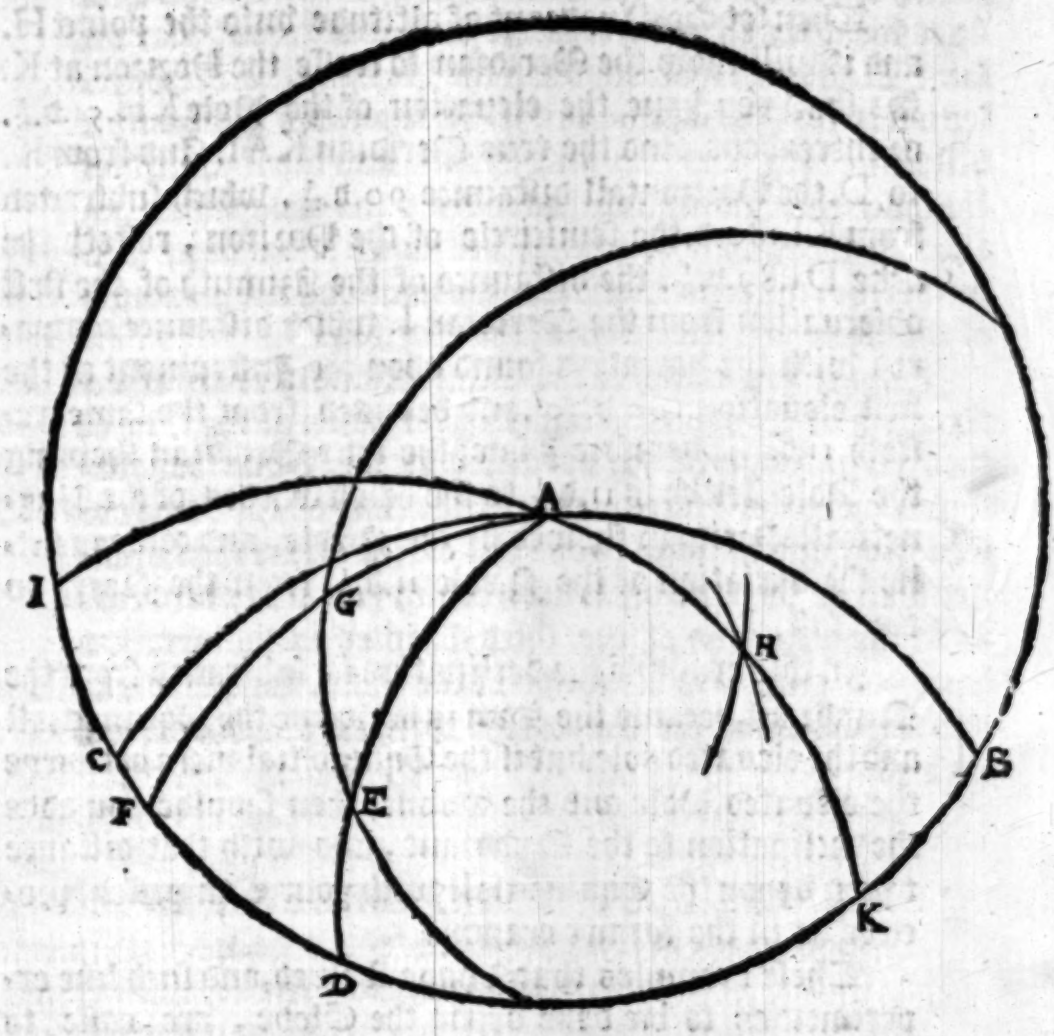
which if you remoue the Quadrant of altitude, you shall finde what the eleuation thereof is. And the point that the same Quadrant sheweth vpon the Horizon, is the intersection of the Meridian and the Horizon, the Horizontall distaunce betwæne this intersection, and the Azimuth of the lesser obseruation, subtracted from the Semicircle, or 180.d. leaueth the Horizontall distaunce of the same Azimuth from the true Meridian. So haue you the eleuation of the Pole, and scituation of the Meridian.

Now if you compare the Horizontall distaunce of the Azimuth of the Sunne, from the Meridian at the time of the obseruation, with the variation by the Suns shadowe found vpon the Instrument, at the time of the same obseruation, and taking the one out of the other, the remainer shall be the true variation, which you are to account, as in the latter end of the third Chapter is shewed. So haue you giuen the eleuation of the Pole, the Meridian, and variation of the Needle, the thinges proposed to bee shewed.

## EXAMPLE OF TWO OBSERVATIONS made at Lymehouse the 29. of Iulie 1581. in the forenoone.

The first eleuation 21.d.0′. Variation. 100.d.30′. from North to West. The second eleuation 50.d.0′. Variation 48 d.0′. from North to West. Difference of the Azimuths.52.d.30′. The declination 16.d.14′. Northerlie.

LEt IDB. bee the Horizon of the Globe. CAB. the Meridian circle. FGA. the Azimuth of the greater eleuation shewed by the Quadrant of altitude vpon the Horizon at F. 10.d. from the Meridian circle of the Globe C. FG. the greater eleuation marked vppon the Globe at G. FD. the




the difference of the Azimuths vpon the Horizon, 52.d.30′. E. the prick of the leſſer eleuation marked vppon the Globe in the Azimuth AED.

Then opening your Cumpaſſes to 73.d.46′. of the Equinoctiall (which is the complement of the declination) and ſetting one end vpon G. the poinct of the greater eleuation, deſcribe with the other end, an arke or peece of a circle at H.

This done, ſet one foot of the Cumpas vnaltered in E. the leſſer eleuation, and with the other end deſcribe a peece of a circle croſſing the former arke at H. this interſecti-

on shall be the eleuated Pole.

Then set the Quadrant of altitude vnto the point H. and it will shew the Meridian to crosse the Horizon at K. So shall you haue the eleuation of the Pole KH. 51.d.½. or thereabout. And the true Meridian KAL. And from K. to D. the Horizontall distaunce 90.d.½. which subtracted from KI. 180.d. the semicircle of the Horizon, resteth the arke DI. 89.d.½. the distaunce of the Azimuth of the first obseruation from the Meridian I. which distaunce compared with the variation found vpon the Instrument at the first eleuation 100.d.30'. and deducted from the same, resteth 11.d.½. Therefore I saie, the true Meridian shewing the Pole Artike is 11.d.½. to the Westwardes of the Magneticall Meridian shewed by the Nædle, and consequentlie the variation of the Nædle 11.d.½. from the Northe to the East.

In this example the declination is subtracted from the Quadrant, because the Sun is betweene the Equinoctiall and the eleuated pole, but if the Equinoctial were betweene the eleuated Pole and the Sunne, then shoulde you adde the declination to the Quadrant, and with that distance taken vppon the Equinoctiall with your Compasses, proceede as in the former example.

These examples that I haue shewed, and such like experimentes to bee done vppon the Globe, are easie to bee conceiued, and the reasons verie manifest: but the truth of the matter consisteth in the exactnesse of the Instruments, and the orderlie application and handling of them.

Note,

I might heere haue annexed the manner, how vppon two obseruations of the Sunnes eleuation in forenoone or afternoone, and difference of the Azimuths, to calculate the premisses more exactlie by the Table of Signes and doctrine of sphericall Triangles: but that it is a verie tedious waie, and my meaning is rather to giue the Reader a proofe of the pleasaunt vse of these calculations

(which

(which I thinke I haue sufficientlie done in the former Chapters) then to cloie him at the first with the hard and painfull practise of many examples. Notwithstanding, for the satisfaction of some, I will briefflie set downe ẏ ground and summe of the worke, which is this.

The complementes of your two eleuations, are two sides of a sphericall triangle not rectangle. The angle by these two knowen sides contained at the Zenith, is giuen by the difference of the Azimuthes or variations vppon the Instrument. Wherefore by the 28. of the 4. of Regiomontanus the third side (which is the arke comprehended betweene the two eleuations) and the other angles maye be giuen.

Then haue you another like triangle, whose three sides are these: the first, one of the foresaid complements of eleuation: the second, the arke of the circle of declination, betweene the Sun at the instant of the same eleuation, & the eleuated Pole. The third side is an arke of the Meridian betweene the Zenith and the Pole: which is the complement of the eleuation of the Pole or latitude of the place. The two first sides are alwaies giuen. For finding the third side, it is necessarie to knowe the angle that the two giuen sides containe, which is the difference of two angles, whereof one is an angle of the first Triangle giuen, the other an angle contained betweene the arke of the circle of declination, and the third side of the first triangle, which angle is diuerselie found, and being found and subtracted from the other angle, or that from it, the difference is the angle of this other Triangle: And so haue you in the spheriall Triangle two sides, and the angle by the same two sides contained, giuen. And by the same 28. of the fourth of Regiomontanus the third side is founde, the complement whereof is the eleuation of the Pole.

And the eleuation of the Pole, and declination of the Sun

Sun being giuen, the fourth Chapter sheweth by one obſ-
ſernation, to finde the variation of the Nëedle.

## Of the Pole of the Magnes.

### The eight Chapter.

DIuerſe learned men haue iudged, and ſet downe as a truth (grounded vpon report) that the Meridian common to the Pole of the world, and the Pole of the Magnes (that is to saie, where the Nëedle touched with the Magnes, sheweth the Pole of the world directly) palleth at the Ilands of ỹ Açores, or nëre there about, (but I finde by great probabilitie, ỹ it should be to ỹ Weſtwards of thoſe Ilands.) From which Meridiã at the Açores, I account the beginning of Longitudes, and finde our Meridian of London, to be from the ſame 23.d.½. our Latitude as before ſaid. 51.d.32′. and the variation of the Cumpas or Nëedle. 11.d.¼. frõ the North to ỹ Eaſtwards. Now vpon theſe grounds I finde by calculation, the Pole of the Magnes, or the interſection of the two Magneticall meridians, vpon the ſuperficies of the earth, to be from the Pole artik 25.d.44′. and in longitude 180.d. that is to ſay, 25.d.44′. in the former common Meridian, on the other ſide of the Pole.

It may be happely that ſome of you will be deſirous to know the waie how this Magnetical pole is found out, that you may applie the ſame to like purpoſe hëreafter. Therefore I thought good to ſet downe the manner of the former calculation, by helpe of the deliniations in the figure following.

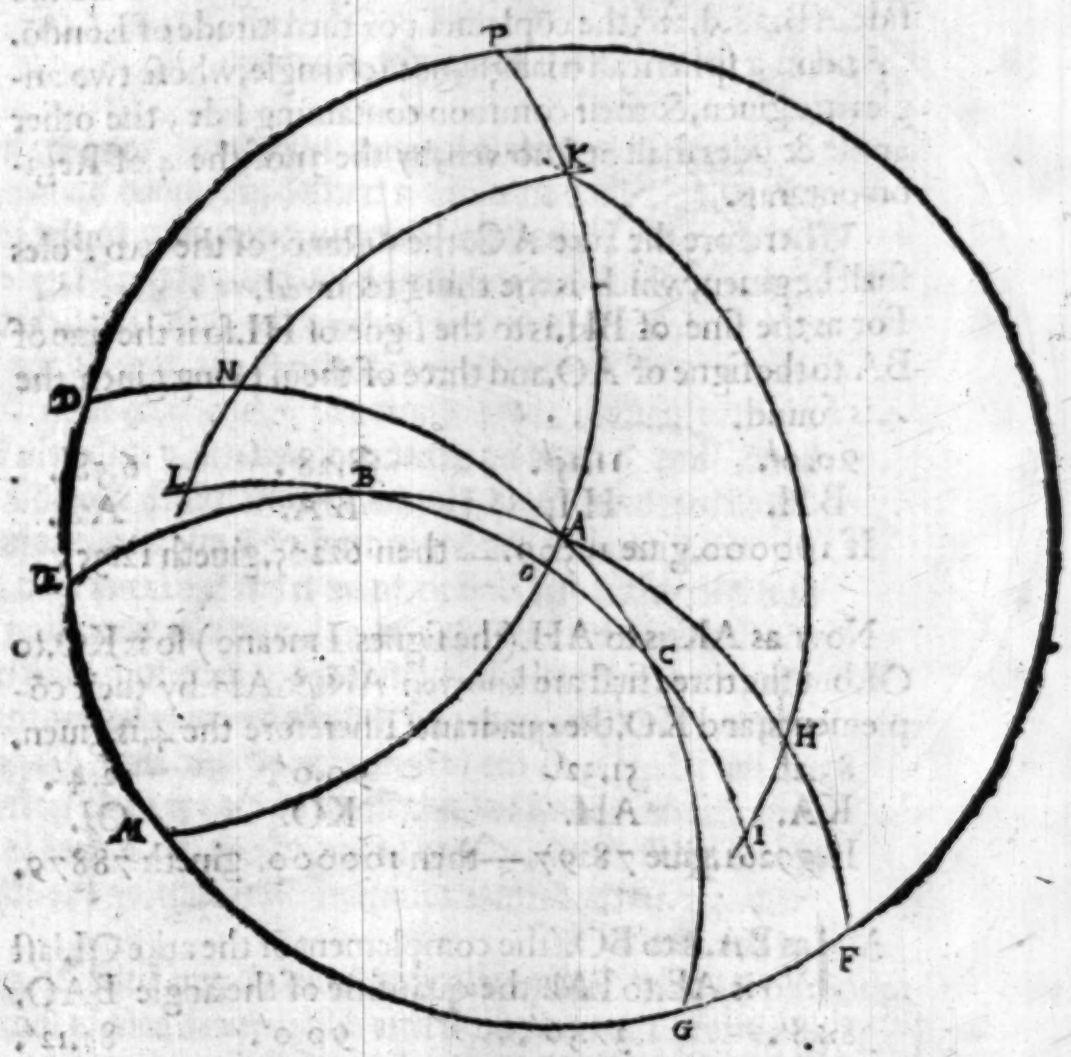
Example.

LEt A be the Pole Artike, PEF. the Equinoctiall, DAG. the common Meridian of the Pole Artike, and Pole of

the

the Magnes. EAF. the meridian of London.

LOI. the Magneticall meridian for London. B. for the place of London. HI. the quantitie of the angle of Variation at the end of the quadrants BH. and BI. C. the inter-




section of the two Magneticall meridians. CL. and CN. two quadrants of the said magneticall circles, including the arke LN. the quantitie of the angle at C. PAM. the Semicircle of a Meridian crosing the Magneticall Meridian of London in the poinct O. at right angles.

Make out the quadrants IHK. and LNK. so shall they crosse themselues with the quadrant OAK. at the poinct K.

Now haue you A B C. a ſpherical triangle, two angles whereof, and the common containing ſide of them, are giuen. A B C. 11. d. ½. the angle of Variation at London. BAC. 156. d. 30′. the complement of the angle D A E. (the difference of the longitudes) to two right angles. And the ſide AB. 38. d. 28′. the cõplement of the latitude of Londõ.

And in a ſpherical triangle, not rectangle, whoſe two angles are giuen, & their common containing ſide, the other angle & ſides ſhall be knowen, by the 31. of the 4. of Regiomontanus.

Wherefore the arke AC. the diſtance of the two Poles ſhall be giuen, which is the thing required.

For as the ſine of BH. is to the ſigne of HI. ſo is the ſine of BA. to the ſigne of AO. and three of them being giuen, the 4. is found.

| 90. 0′. | 11. 15′. | 38. 28′. | 6. 58′. |
|---|---|---|---|
| B H. | H I. | B A. | A O. |

If 100000. giue 19509. — then 62205. giueth 12135.

Now as AK. is to AH. (the ſignes I meane) ſo is KO. to OI. but the three firſt are knowen AK. & AH. by their cõplements, and KO. the quadrant. Therefore the 4. is giuen.

| 83. 2′. | 51. 32′ | 90. 0′. | 52. 4′. |
|---|---|---|---|
| K A. | A H. | K O. | O I. |

If 99261. giue 78297. — then 100000. giueth 78879.

And as BA. is to BO. (the complement of the arke OI. laſt found:) ſo is AE. to EM. the quantitie of the angle BAO.

| 38. 28′. | 37. 56′. | 90. 0′. | 81. 12′. |
|---|---|---|---|
| A B. | B O. | A E. | E M. |

If 62205. giue 61474. — then 100000. giueth 98824.

So hauing EM. 81. d. 12′. the quantitie of the angle BAO. I ſubtract the ſame from EG. 156. d. 30′. the quantitie of the whole angle BAC. reſt MG. 75. d. 18′. the quantitie of the angle CAO. to the which is equal the oppoſit angle PAD. And as AP. is to PD. ſo is AK. to KN.

| 90.0′. | 75.18′. | 83.2′. | 73.46′. |
|---|---|---|---|
| AP. | PD. | AK. | KN. |

If 100000. giue 96726. —then 99261. giueth 96011.

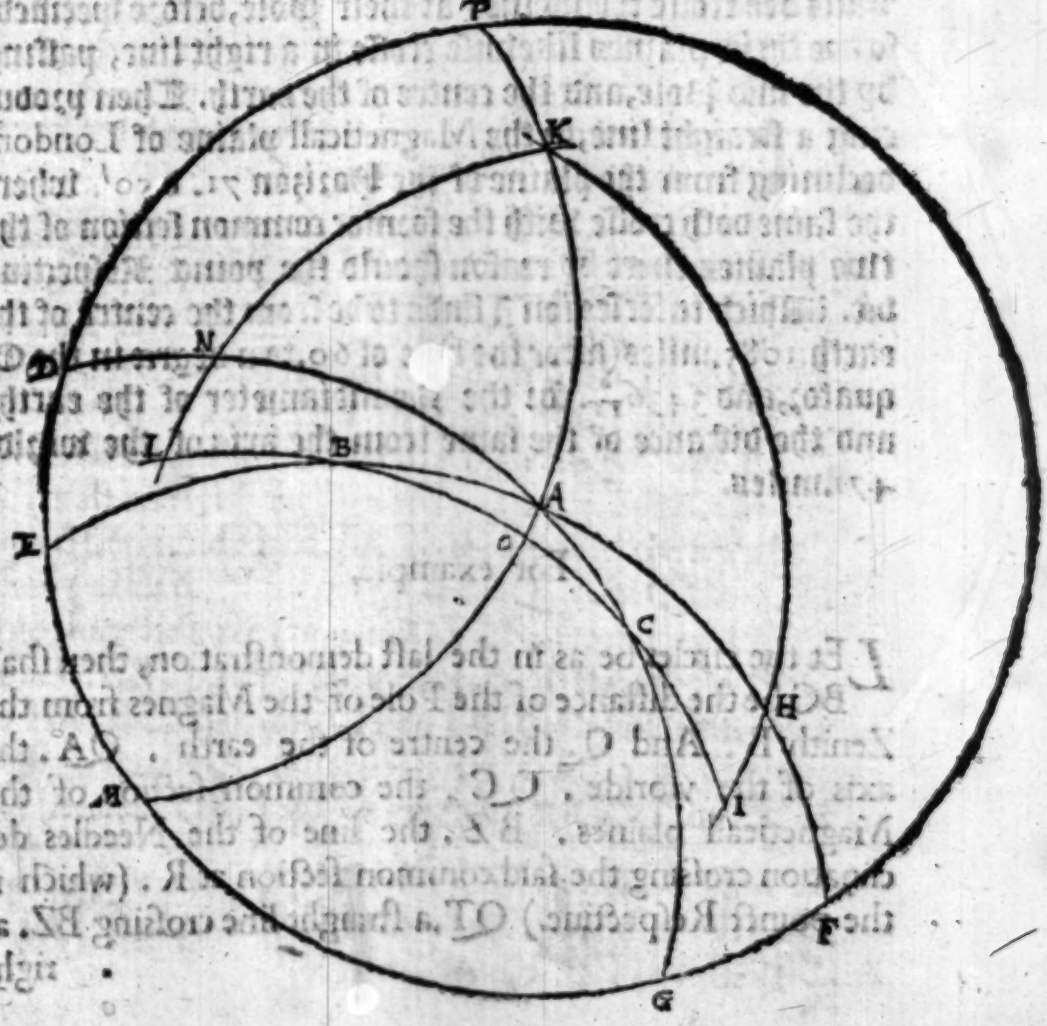
The complement of which arke KN. is NL. 16. d. 14′. the quantitie of the angle ACB. And as NL. is to NC. so is AO. to AC. Wherefore I saie.

| 16.14′. | 90.0′. | 6.58′. | 25.44′. |
|---|---|---|---|
| NL. | NC. | AO. | AC. |

If 27954. giue 100000. —then 12135. giueth 43410.

Which is the distance of the Pole of the Magnes from the Pole artike vpon the former Hypothesis, the thing that was sought.





## Of the poinct Respective.

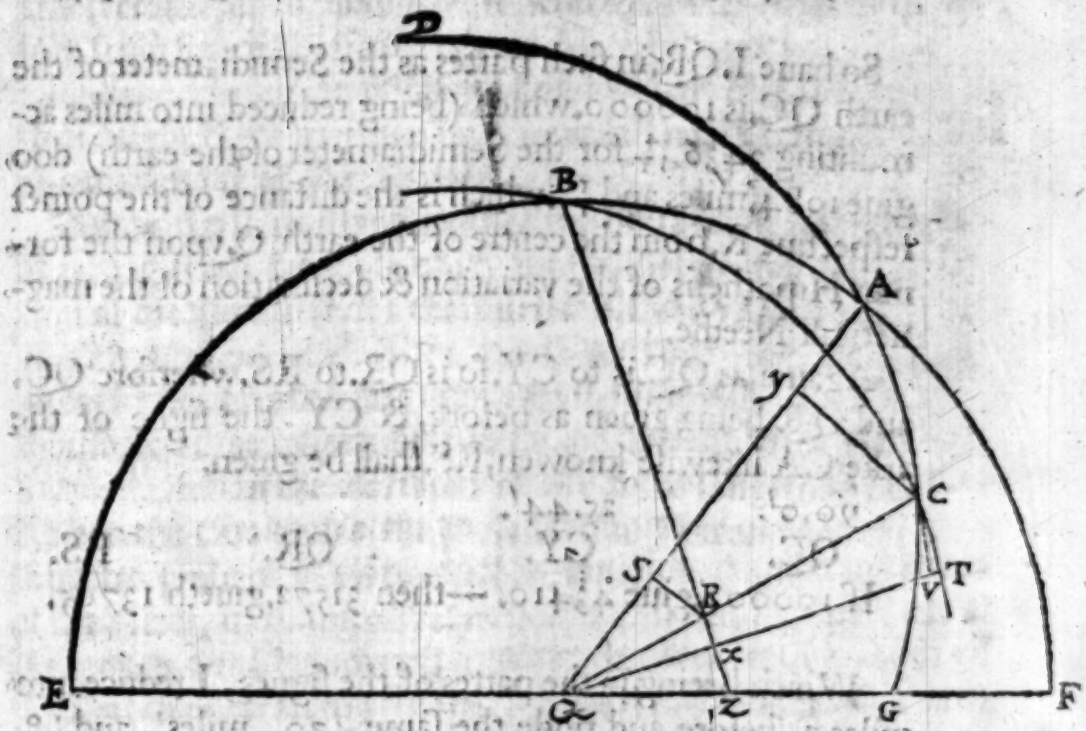
### The ninth Chapter.

HAuing shewed in the former Chapter, vpon the grounds therein specified, the place of the Pole of the Magnes, vpon the superficies of the earth: there resteth now to bee declared of the poinct Respective, where it should be, by the new propertie found of the declining of the Needle, beeing at this place for London, 71.d 50′. as in the former treatise by R. Norman.

First it is to be considered, ỹ as the Magneticall meridians doe crosse themselues at their Pole, before specified: so doe their plaines likewise crosse in a right line, passing by the said Pole, and the centre of the earth. Then producing a straight line, in the Magneticall plaine of London, declining from the plaine of the Horizon 71. d. 50′. where the same doth crosse with the former common section of the two plaines, there by reason should the poinct Respective bee. Which intersection I finde to be from the centre of the earth. 1085. miles (after the rate of 60. to a degree in the Equator, and $3436\frac{4}{11}$. for the Semidiameter of the earth) and the distance of the same from the axis of the world. 471. miles.

For example.

LEt the circles be as in the last demonstration, then shall BC. be the distance of the Pole of the Magnes from the Zenith B. And Q. the centre of the earth. QA. the axis of the worlde. QC. the common section of the Magneticall plaines. BZ. the line of the Needles declination crosing the said common section at R. (which is the poinct Respective.) QT. a straight line crosing BZ. at right




right angles in X. QR. the distance of the poinct Respectiue from the centre of the earth. RS. the distance thereof from the axis. First it is requisite to knowe the quantitie of the arke BC. which is thus found, as the signe of the angle ABC. 11. d. 15'. hath vnto the signe of the arke AC. 25. d. 44'. So hath the signe of the angle B A C. 156. d. 30'. (which is all one with the signe of the angle BAD. the difference of Longitude 23. d. 30'.) to the signe of the arke BC. which is 62. d. 46'. Now as QV. is to QC. so is QX. to QR. But the three first are knowen QV. the second right signe of the arke CT. 9. d. 4'. (the difference of the arke BT. 71. d. 50'. And BC. 62. d. 46'.) Then QC. the Semidiameter or whole signe, and QX. the second right signe of the arke BT. Wherefore QR. shall be giuen by the 4. of the sixt of Euclide.

80. 56'. 90. 0'. 18. 10'.

QV. QC. QX. QR.

If 98750. giue 100000. ——then 31178. giueth 31572.

So haue I. QR. in ſuch partes as the Semidiameter of the earth QC. is 100000. which (being reduced into miles accounting 3436. $\frac{4}{11}$. for the Semidiameter of the earth) doo giue 1084. miles and $\frac{10}{11}$. which is the diſtance of the poinct reſpectiue R. from the centre of the earth Q. vpon the former Hipotheſis of the variation & declination of the magneticall Needle.

Againe, as QC. is to CY. ſo is QR. to RS. wherfore QC. and QR. being giuen as before, & CY. the ſigne of the arke CA. likewiſe knowen, RS. ſhall be giuen.

90.0′. 25.44′.
QC. CY. QR. RS.
If 100000. giue 43410. —then 31572. giueth 13705.

Which beeing in the partes of the ſignes, I reduce into miles as before, and finde the ſame 470. miles, and $\frac{10}{11}$. which is the diſtance of the poinct Reſpectiue R. from the axis of the world QA. By the former Hypotheſis.

## Of the application of the Variation, to the vſe of Nauigation.

The tenth Chapter.

VPon the Hypotheſis of the pole of the Magnes on the ſuperficies of the Earth, and the poinct Reſpectiue in the bodie thereof, according to the former calculations, might be inferred many pleaſaunt concluſions, both for the longitude and latitude of places. But as touching the poinct Reſpectiue by the declining of the Needle, ſeeing this is the firſt and onelie experiment that hath beene made of it, I cannot inferre anie further matter thereof, then that which I haue alreadie ſet downe, vntil by obſeruations in other places, we finde how it will holde.

And

And as for the variation, if it were generallie regular and certaine, as in some part it seemeth to bee: (that is to saie, from hence Westwardes to Meta Incognita, Newfoundland, Florida, and that part of the coast of America) then might there be giuen by it generall rules, commodious for the vse of Nauigation.

And by the same Hypothesis of the Pole of the Magnes at 25.44′. from the Pole of the world, the greatest variation of the Nædle in the Equinoctiall, should be (at 90.d. of Longitude) 25.44′. from North to East, and consequentlie the greatest variation in the paralell of 70.d. should be (at the longitude of 128.d.51′.) frō North to East 81.d.14′. And in the meridian of 180.d. of longitude betweene the two Poles (the Pole Artike I meane) and the supposed Pole of ẏ Magnes,) there should ẏ North point of the Nædle or Cumpas respecting his owne pole) shew the South, & the South point the North pole of ẏ world.

But in my trauailes to the Northeast partes, I haue found this position of the magneticall Pole cleane reuersed: for where as the angle of Variation from hence Eastwards, in the paralell of 70.d. should encrease and grow wider, till it came to 81 d.14′. from North to East as before. At the Iland Vaigats being in longitude from London 58.d. and in the same paralell of 70.d. where, by the former Hypothesis, the variation should be 49.d.22′. from North to East. I finde the Nædle to varie 7.d. from North to West. And ẏ like effect I haue found by diuers obseruations in sundrie other places of the East partes. Which obseruations with many more that I haue caused to be made, and dailie procure to be done in diuerse other Countries, I reserue, with intent (if it be possible) to finde some Hypothesis for the saluing of this apparant confused irregularitie.

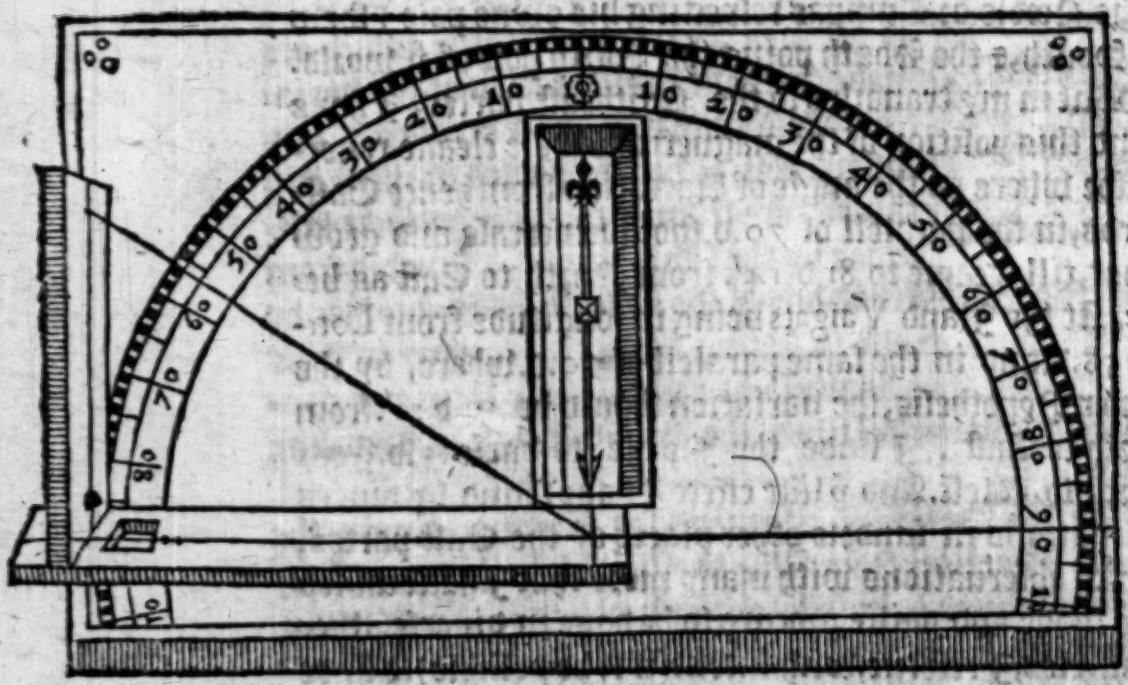
At Ratisbona or Regensburg in Bauaria, beeing in latitude 48.d.52′. and in longitude 36.d.20′. wher, by the former position of the magneticall Pole at 25. d. 44′. the

Variation

Variation should be 16.d.44′. from North to East. Gerardus Mercator found the same to be onelie 11.½. as I gather by his placing of the magneticall Pole at 16.d.22′. frō the Pole Artik vpon his obseruation made at that place: which confirmeth the retrograde qualitie in the variation from hence Eastwards, as afore said.

Which strange varietie, I haue heere plainly proposed, to the end that the learned sort might consider thereof, and sharpning their wits, see what probable causes & grounds they can alligne for the same. For considering it remaineth alwaies constant without alteration in euerie seuerall place, there is hope it may be reduced into method & rule.

A new Instrument for the Variation.




BEcause I haue found some imperfections in the first Instrument for the variatiō (which notwithstanding doth far excell ỹ Compasses of variation heretofore vsed for that purpose) I haue heere set down the forme of a new

Instrument

Instrument, wherein all scruple of doubtes & defects that might growe by other is quite auoided. Which beeing once exactlie placed with the Needle vppon the line of South & North, wil serue without remouing for a whole daies obseruation, the Inder onelie beeing carried about with the Sunne, to giue the degrees of Azimuth vpon the Instrument by the shadowe of the line thereof, and is otherwise to be vsed according to the prescript rules of the former Instrument.

## Of the inconueniences and defects in sailing, and in description of Countries, caused by the variation of the Cumpas.

### The eleauenth Chapter.

IN all Sea Chartes generallie, which are made without consideration of the variation, are committed great errours & confusion. For, either the partes in them contained, are framed to agree in their latitudes by the skale thereof, & wrested from the true courses that one place beareth from another by the Cumpas, or else in setting the partes to agree in their due courses, they haue placed them in falle latitudes, or abridged, or ouerstretched the true distaunces betweene them.

In the Marine Plats made for Newfoundland, the course set downe from Sillie to Cape Raso is due West, which is found to be so by our common sailing Cumpasse, whose wiers are set $\frac{1}{2}$. a point from North to East, notwithstanding Sillie being in latitude 50. d. little more. Cape Raso in Newfoundland is found to be but in 46. d. $\frac{1}{2}$. which is 3. d. $\frac{2}{3}$. lesse then the latitude of Sillie.

To make a shew of reformation of this error, (caused by the Variation and setting of the wiers in the Cumpasse) or to giue a light of that difference in latitude, they

haue placed in the plat against that coast, a new scale of latitude, some vpon the line of South and North, and some other haue placed the same vpon the line of North Northeast, and South Southwest (because that point of the Compasse sheweth the pole nerest in that place) and haue furnished the degrées thereof agréeable to the latitude of Cape Raso: and by that meanes haue had a double scale of latitude, one for the Easter coasts, the other for that West. But how farre the same hath bene from reforming the errour, or giuing anie helpe to Nauigation, you may easilie iudge.

Others to auoide that errour of the difference in latitude in that voiage and course, haue vsed Compasses, whose wiers haue bene set directlie vnder the North point, and thereby sailing West from Sillie, haue fallen to the Northwards of Cape Raso about 50. leagues, and in latitude nére 49. d.

Some other haue vsed in the same voiage to place a blanke Flie vpon their sailing Compas, which they haue remoued from time to time, as they haue iudged the variation hath altered, by which way, albeit they may séeme to kéepe themselues nérer the Paralell, yet the same in Nauigation worketh the greatest confusion of all other, and therefore is to be vtterlie abolished.

In our voiages from hence Eastwards to S. Nicholas in Russia, and to the Narue in Liuonia, &c. the Marine Plats of the coasts are described by our common sailing Compasse, with consideration of the variations at diuers places, wherby the true Meridians reformedlie set down, declining from the Paralell meridians of the Plat, doe necessarilie widen Northwardes, and straighten to the Southwards, contrarie to the true forme and nature of Meridians. And yet nothwithstanding, that is the best meanes hetherto knowen, to reforme in Plat, the errours that else would grow by the straunge variations that waie.

And albeit these places serue verie well for those Nauigations, yet by menes of the variations considered, the forme of those coastes is so disforted from the right shape it should beare, bæing truelie described vppon the Globe or otherwise in plaine, according to the true latitude and longitude: That wheras ẏ Narue (bæing in latitude 59.d.½. and in longitude from the Meridian of London 26.d.10′.) should be from S. Nicholas 9.d.40′. in longitude to the Westwardes (S. Nicholas bæing in latitude 64.d.35′. and in longitude from London 35.d.50′.) In the sailing Plat it is brought to be in the Meridian of Colmogorod, (which is in latitude 64.d.20′. and in longitude frõ London 37.d.45′.) which is 1.d.[illegible]′. to the Eastwards of the Meridian of S. Nicholas.

In the Mediterranean Sea, and in the coastes thereof, where in great reason should be the perfectest descriptions of the world, for that in those partes haue ben the seates and abodes of the most famous and learned men in all ages, we sæ notwithstanding in the Marine plats of those partes, grose errours committed, through want of knowledge of the variation, and the vse thereof, in which they haue not accounted of 3.4.or 5. degrees errour in the latitude of places.

But those defects of the latitudes haue bene verie well reformed, by the famous and learned Gerardus Mercator (whom I honour and esteeme as the chiefe Cosmographer of this time) in his vniuersall Map, which though he haue made with sailing lines, & dedicated to ẏ vse of Sea men, yet for want of consideration of the variation, the same is more fit for such to behold, as studie in Cosmographie, by reading authors vpon the land, then to be vsed in Naugation at the Sea.

There is also in the same vniuersall Mappe, and likewise in all other moderne Maps of ẏ North parts of Europe, a great fault, by placing two Wardhouses distaunt one from the other aboue 20. d. in longitude, whereas

in déede they are but one thing, and no such distaunce betweene them. This errour hath growen by taking Wardhouse, and the Sea coasts, from thence to S. Nicholas, Vaigats, and the Ob. &c. out of the Map of that worthie trauailer M. Anthonie Ienkinsons his iourneies to Boghar & Persia, &c. In the which I placed that border of the Sea coast, and for some causes went no further Westwardes in that description, then Wardhouse, which is in latitude 70. d. $\frac{1}{3}$. and in longitude from London 29. d. Wherefore to accomplish the whole border of that coast, he was forced to séeke some other description to ioyne with it, and toke as appeareth the Map of Olaus Magnus of the North Countries, wherein he found likewise Wardhouse, but falsely placed, in latitude about 19. d. too much, & in longitude as much too little; the which, although he might take to be the same specified in Master Ienkinsons Map, yet he was constrained to separate them the sayd distance of 20. d. in longitude (or to leaue there so much superfluous roome) otherwise hee should haue thrust the South partes of those Countries togethers, and confounded the whole description.

And albeit he had had the entire sailing Plat, that weere vse for those partes, yet if he had not knowen the secret effect of the Variation in the making therof, he might haue fallen into the like absurditie or worse. But of those coasts and of the inward parts of the Countries, Russia, Muscouia, &c. I haue made a perfect Plat and description, by mine owne experience in sundrie voiages and trauailes, both by Sea and Land to and fro in those partes, which I gaue to her Maiestie in Anno 1578.

Besides these and like imperfections proceeding of the Variation, there is yet another inconuenience, which oftentimes increaseth the former errours, and that is, the diuerse placing of the wiers fixed to the Flie of the Compasse.

This varietie of setting the wiers, hath caused great

confuſion in Nauigation, and in other accountes of Sea cauſes, for when it is ſaid, that from ſuch a headland, to ſuch a place is ſuch a courſe, or at ſuch a place the Moone vpon ſuch a point of the Cumpaſſe maketh the full Sea, it is requiſite to be demaunded, by what Cumpaſſe the obſeruation was made, whereas if the wiers had not ben altered from the North point of the Flie, (which I wiſh had neuer bene anie where) theſe doubtes had bæne auoided.

It behoueth therefore all men that will make Hydrographicall deſcriptions for the vſe of ſailing, to haue ſpeciall regard of the Cumpas by which theſe obſeruations are made, and if they collect notes made by ſundrie Cumpaſſes of diuerſe ſets, they ought to reduce all the varieties vnto ſome one certaine, and to giue notiſe of the ſame in their plat: And not to make a confuſed mingle mangle by ioyning together all varieties of obſeruations, notes and reportes, as the Portingales and Spaniards haue done, in compounding theſe North partes of the world, with their owne diſcoueries, without conſideration of the diuerſe ſortes of the ſeuerall Cumpaſſes by which they were made.

Alſo it importeth all Maſters, Pilots, and others by what name ſo euer, that ſhall giue directions in Nauigation, to looke circumſpectlie to the ſetting of the wiers of the Cumpaſſe by which they ſhall ſaile, that the ſame Cumpas be correſpondent, to the lines of the Sea Carde that they ſhall vſe: that is to ſaie, that it be of the ſame ſet for the Variation, that the Cumpaſſe was of, by which the Card was made.

And ſeeing we haue in this our Countrie acquainted our ſelues commonly in our obſeruations and Nauigations, with ŷ Cumpaſſe, whoſe wiers are ſet at $\frac{1}{4}$. a point from North to Eaſt, I meane in the deſcriptions that I ſhall make, to applie the ſame agreeable to the ſaid Cumpaſſe, and would vſe the like without alteration (and al-

so the straight lines in Sea Cardes) if I shuld saile round about the worlde to make the description thereof, but alwaies with regard of the seuerall variations of euerie place where the same should be obserued.

## Of the Instruments and rules of Nauigation.

### The twelfth Chapter.

AMongst the Rules and Instrumentes for Nauigation, all such are vaine & to small purpose, wherein the true Meridian is presupposed to be giuen by the magneticall Needle, without due consideration of the variation, for ỹ they are all grounded vpõ false suppositions. Hereby it commeth to passe ỹ one Michael Coignet of Antwerp, in his New instruction (as he tearmeth it) of the most excellent and necessarie poinctes of Nauigation, wherein he sheweth the making and vse of a Nauticall Hemisphere, which he preferreth before all other Sea Instruments, is verie childishlie abused. For whereas he pretendeth by it, to giue the eleuation of the Pole, and the houre and instant of the time of the daie, by anie one obseruation in anie place, besides that, it is of all other that hath hetherto haue bene vsed at Sea, the most tedious and vnfit for that purpose, it is also by reason of the variation not considered, meere false and erronious. For the true Meridian (which is the ground of his purpose, is as farre to seeke as the thing he promiseth to giue by the same. The like may be saide of all other Instrumentes made vppon the same ground, whether they serue for the sea or land.

The same author in the 4. Chapter of his booke, entreating of sailing vpon the poinctes of the Compasse, saith, that in sailing South or North he shall passe by the poles

of the worlde, and kéepe vnder one Meridian, till he come to the place from whence he first departed. And vpon the poincts of East & West out of the Equinoctiall, hée shall saile vnder a paralell, till he retourne to the place from whence he went. But in sailing vpon ỳ poinct of North-east, he shall describe a spirall line inclining by little and little towards the Pole, as in his demonstration thereof in the same Chapter appeareth. But for want of due consideration of the variation, his rules, reasons, and demonstrations, and such others hitherto giuen for like purposes, are friuolous and false.

For if he direct his sailing by the Cumpasse (as of necessitie he must, being the onelie Instrument for that purpose) it is manifest, that whether he saile North or South, East or West, or by what other poinct so euer, the Cumpasse not respecting alwaies the Pole of the worlde, as he supposeth, but some other poinct or poincts distant from the same, shall leade him accordinglie, whereby hée shal neither kéepe vnder one Meridian, nor vnder one paralell of latitude, neither make such a spirall line to the Pole of the worlde as he demonstrateth. His fault in setting downe those rules is so much the greater, in that he acknowledgeth in the Chapter next before the variation at Antwerp, to be about 9. d. from North to East according to Mercators position, of the Magnetical Pole, which hée also confirmeth by his owne experience.

But it séemeth he hath followed, that excellent Mathematician Petrus Nonius, especiallie concerning the sailing vpon the poincts of East & West. For he, in his first booke of the rules and Instrumentes of Nauigation, enforceth himselfe to proue and demonstrate, that in sailing East or West, out of the Equinoctiall, the course is performed by péeces of great circles, and yet describeth a paralell. But how that may stand with the principles of Geometrie, I referre the iudgement to the expert Mathematicians, for it is like as a circle shoulde bée

made

made of straight lines, which is impossible.

It appeareth in the discourse that he hath made of those matters, that he had not a right iudgement of the nature of the Compasse in sailing (admitting the same to shew the Pole without Variation) for if he had, he would neuer haue entered in such a Labyrinth as he did. But he thought it a great absurditie that the Compasse in euerie Horizon, should shew the Meridian and Poles of ỹ world by the poincts of South and North, and by the poincts of East and West, to shew in the Horizon the verticall and Equinoctiall East and West, (being a great circle) and yet in sailing East or West, except in the Equinoctiall, it should performe but a paralell.

But it is to be vnderstode, that albeit the poinctes, or lines of the Compas do alwaies in euerie Horizon represent great circles in the Heauens, the poinctes of South and North the Meridian, and the poincts of East & West the verticall circle of East and West, each crossing other at right angles, and likewise of the poincts. (The reason whereof is, because the Compas lieth euerie where leuel with the Horizon, so as a perpendicular line descending from the centre thereof at right angles with the plaine of the same, will alwaies fall vppon the centre of the earth, and consequentlie be the Semidiameter of a great circle.) So that whersoeuer the Compas be carried, these circles are supposed to be carried about with it, and the view of euerie thing in the Horizon represented by the poinctes thereof, is likewise in great circles: Yet in sailing by the Compas, the poincts of South and North onely, describe great circles generallie, which are the Meridians, and the poincts of East and West, describe a great circle in the Equinoctiall onelie: in all other places out of the Equinoctiall, they describe but parallells. And the sailing vppon anie other poinct of the Compasse, from anie place, describeth a spirall line, according to the angle it maketh with the Meridian. And hereby in sailing vppon the

poincts

poincts of East or West, out of the Equinoctiall, (the North poinct allwayes respecting the Pole) the course performeth a Paralell, according to the distaunce of the centre of the Cumpasse from the Pole. The manner thereof you may perceiue by fastning a small thrid or Virginall wier at the Pole of a Globe, or centre of a circle, which shall representa moueable meridian to be carried about the Globe or circle, and fire vpon the same, a small Flie of a Cumpasse, so as the line of South and North bee answerable to the thrid or wier, and the North poinct thereby alwaies respect the North Pole: then in turning the thrid about the Globe or circle, vpon the pole or center, if the center of ỳ Flie be out of the Equinoctiall, (betweene it & the pole) albeit the poincts of East & West crossing the same line & moueable meridian at right angles, do shew the verticall East and West vpon the Globe, which is a great circle, yet in carrying ỳ same Flie vpon the thrid or moueable meridian, about the Pole or center, you shall by the centre of the same Flie, describe but a paralell, according to the distance thereof from the Pole of ỳ Globe, or center of the circle, not vnlike the circular motion of a horse drawing in a Mil, who though he loke forth straight in a right line, yet being fastned to the beame of the mill, is forced to make his course in a circle, whose Semidiameter is the length of the beame contained betweene the Horse, and the centre of the mill or milpost.

And as in the Equinoctiall, the line of South & North in the Cumpas (by supposition representing the meridian) is paralell to the Axis of the Earth, (which is the common section of all the meridian plaines,) and the line of East and West, crossing the same Axis of right angles, representeth the verticall East and West, which is the Equinoctiall, imagining to descend from the centre of the Cumpasse a line, to fall perpendicularlie, and at right angles with the Axis of the world (which shall be at the centre of the earth) and in sailing East or West by the Cum-

passe, the imagined perpendicular line being carried a-bout with ye same (making alwaies right angles with the Axis) shall describe the plaine of the Equinoctiall, equidistant from the Poles of the world, and at right angles with the Axis: ye point of the same line at the centre of the Compasse, the circumference of the Equinoctiall, vpon the superficies of the Sea: So being from the Equinoctiall on either side, imagining the line of South and North in your Compasse to represent alwaies the Axis of the world, and to lie paralell with it, the line of East and West must crosse the same Axis alwaies at right angles: and supposing a line to fall from the centre of your Compasse to the Axis of the world, making right angles with the same Axis. In sailing East or West, that imagined line beeing carried about with the Compasse (alwaies at right angles with the Axis) shall describe the plaine of a paralell, equidistant to the plaine of the Equinoctiall, and the point thereof at the centre of the Compasse, the circumference of the paralell vpon the superficies of the Sea: which Paralell should be represented by the points of East and West of the Compasse, if the line of South and North of the same were paralell to the Axis of the Poles, as was supposed, but it is not. And therefore as they decline one from the other, so doth the verticall circle of East & West shewed by the Compas, decline from the paralell circle euerie where.

Necessary note.

The angle of which declination is alwaies equall to the latitude of the place or distaunce of the paralell from the Equinoctiall.

But as I haue alreadie sufficientlie declared, the Compasse sheweth not alwaies the Pole of the world, but varieth from the same diuerslie, and in sailing describeth circles accordinglie. Which thing if Petrus Nonius and the rest that haue written of Nauigation, had soyntlie considered in the tractation of their rules and Instruments, then might they haue bene more auaileable to the vse of Naui-

Nauigation, but they perceiuing the difficultie of the thing, and that if they had dealt therewith, it would haue vtterlie ouerwhelmed their former plausible conceites, with Pedro de Medina (who as it appeareth hauing some small suspition of the matter, reasoneth very clarklie, that it is not necessarie that such an absurditie as the variation, should be admitted in such an excellent art as Nauigation is) they haue all thought best to passe it ouer with silence. But I hope such as intend hereafter to write of Nauigation, will either frame their rules, precepts, and Instruments, with regard of the Variation, as herein I haue shewed, or else ease themselues of that trauaile, for as good none as vnprofitable.

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